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نموذج رقم (١٨)
اقرار والتزام بالمعايير الأخلاقية والأمانة العلمية
وقوانين الجامعة الأردنية وأنظمتها وتعليماتها
لطلبة الماجستير

أنا الطالب: كريستينا وصفي كرم جلاب الرقم الجامعي: (٨٠٩٠٩١٢)

تخصص: الإدارة المتكاملة للموارد المائية الكليـــــة: العلوم

عنوان الرسالة: إدارة الطلب على المياه كأداة لتقليل العجز في الموازنة المائية لحوض دمشق السورية

اعلن بأنني قد التزمت بقوانين الجامعة الأردنية وأنظمتها وتعليماتها وقراراتها السارية المفعول المتعلقة باعداد رسائل الماجستير عندما قمت شخصيا" باعداد رسالتي وذلك بما ينسجم مع الأمانة العلمية وكافة المعايير الأخلاقية المتعارف عليها في كتابة الرسائل العلمية. كما أنني أعلن بأن رسالتي هذه غير منقولة أو مستلة من رسائل أو كتب أو أبحاث أو أي منشورات علمية تم نشرها أو تخزينها في أي وسيلة اعلامية، وتأسيسا" على ما تقدم فانني أتحمل المسؤولية بأنواعها كافة فيما لو تبين غير ذلك بما فيه حق مجلس العمداء في الجامعة الأردنية بالغاء قرار منحي الدرجة العلمية التي حصلت عليها وسحب شهادة التخرج مني بعد صدورها دون أن يكون لي أي حق في التظلم أو الاعتراض أو الطعن بأي صورة كانت في القرار الصادر عن مجلس العمداء بهذا الصدد.

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WATER DEMAND MANAGEMENT AS AN INSTRUMENT TO REDUCE THE NEGATIVE WATER BALANCE IN THE DAMASCUS BASIN, SYRIA

By

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COMMITTEE DECISION

This Thesis/Dissertation (Water Demand Management as an Instrument to Reduce the Negative Balance in the Damascus Basin, Syria) was Successfully Defended and Approved on 19/1/2010

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List of Abbreviations

ACB	Agricultural Cooperative Bank
ACSAD	Arab Center for the Studies of Arid Zones and Dry Lands
BGR	German Federal Institute for Geosciences and Natural Resources
CES	Consulting Engineering Salzgitter
CWR	Crop Water Requirements
DAWSSA	Damascus Water Supply and Sewerage Authority
DMA	Damascus Metropolitan Area
DWR	Directorate of Water Resources
ESCWA	Economic and Social Commission for Western Asia
FAO	Food and Agricultural Organization
GCEA	Commission for Environmental Affaires
GCSAR	General Commission for Scientific Agricultural Research
GCWR	General Commission for Water Resources
GDP	Gross Domestic Product
GTZ	German Technical Cooperation
HWC	Higher Water Council
IWRM	Integrated Water Resource Management
JICA	Japan International Cooperation Agency
LCD	Liter per Capita per Day
MAAR	Ministry of Agriculture and Agrarian Reform
MCM	Million Cubic Meters
MLAE	Ministry of Local Administration and Environment
MOHC	Ministry of Housing and Construction
MOI	Ministry of Irrigation
MOInd	Ministry of Industry
MOT	Ministry of Tourism
NAPC	National Agricultural Policy Center
NEAP	National Environmental Action Plan
NPCMI	National Project for Conversion to Modern Irrigation
PIM	Participatory Irrigation Management
SAC	Supreme Agricultural Council
SASMO	Syrian Arab Organization for Standardization and Metrology
SPC	State Planning Commission
SYP	Syrian Pound
TDS	Total Dissolved Solids
UFW	Unaccounted For Water
UNDP	United Nations Development Program
UNESCWA	Economic and Social Commission for Western Asia
USSR	Union of Soviet Socialist Republics
WB	World Bank

WDM	Water Demand Management
WRIC	Water Resources Information Center
WTO	World Trade Organization
WUA	Water Use Associations

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ABSTRACT

The Damascus Basin as a hydrological unit presently exhibits a negative water balance. More water is being used than naturally recharged. This leads to a falling groundwater table, which in turn decreases the water availability for human consumption and agricultural practices.

In the present study different water demand management scenarios, as part of Integrated Water Resource Management (IWRM), to alleviate the negative water balance were assessed individually. These focused on water savings in the domestic and agricultural sector that are together using 80% of all resources.

For the agricultural sector a total possible water saving of 28% by conversion to modern irrigation techniques was estimated with further saving potential through a change in cropping pattern and higher conveyance efficiency. The domestic sector scenario projected an increased water demand for the year 2025, caused by a rapidly growing population and thereby cancelling out part of the agricultural sector savings. The total domestic and agricultural demand for the year 2025 was predicted to be 84% of today's demand, still more than the available resources, causing a negative water balance.

To reach sustainable water management for the Damascus Basin strong efforts exceeding today's to reduce the demand, increase water efficiency and water reuse have to be taken.

Keywords: irrigation, water demand management, Damascus Basin, water balance

1 General Introduction

1.1 Introduction

Damascus faces a severe water shortage as demand increases beyond supply. Urban growth and climate change are the main drivers for an increase of the predicted water demand for the year 2025. The Damascus Basin already faces a yearly water deficit of 311 Million Cubic Meters (MCM) (Varela-Ortega, 2003). Tackling only the supply side, such as tapping new resources, storing water in the wintertime, when most of the rain falls, and further treatment to comply with drinking water standards of groundwater is not sufficient. Other options must be considered. One option lies in the more efficient use of water through modern irrigation techniques in the agricultural sector or the modernization of the supply network in the domestic sector. On the other hand a suitable legal framework has to be developed to strengthen the water demand management (WDM) in all sectors.

This study is part of an ongoing German Technical Cooperation (GTZ) project in cooperation with Consulting Engineering Salzgitter (CES) on institutional advice to the local water supplier, the Damascus Drinking Water Supply and Sewerage Authority (DAWSSA). The project is about the assessment of the water production of drinking water wells in Rural Damascus and the water balance in general. The major water resource of the Damascus Basin is groundwater. For several decades this resource has been greatly affected by over abstraction and intensive agricultural use.

Until the beginning of the 21st century Syrian policies were directed towards supply management for reasons as to achieve food security. This resulted in a declining water table, and a deteriorating water quality through both over abstraction and over

fertilization. Today six out of seven Syrian hydrological basins are running a deficit totaling over 3000 MCM (NAPC, 2009a). The government has acknowledged this development and the concept of Integrated Water Resource Management (IWRM) has partly been added for the first time in the 10^{th} five-year plan concerning the years 2006-2010. The new policies aim to use the resources more efficiently through modern irrigation methods and to preserve groundwater aquifers as a reserve for future generations (Rabboh, 2007). The change from water supply to WDM is vital to sustain the development of the country.

Importance of this study to the region

The importance of this study to the region is to show potentials on how to secure the future water supply of Greater Damascus in an integrated manner. This involves both the domestic and the agricultural sectors which will be studied in detail. Greater Damascus is the most populous area in Syria with about 5 Million people, representing about 25% of the total population. The domestic sector in the Damascus Basin consumes 19% of the total available water resources, the highest proportion in Syria. But the main consumer, as in whole Syria, is the agricultural sector with a consumption of 76% compared to a national average of 90% (Varela-Ortega, 2003). In this study it is assessed whether reducing the agricultural demand by improving irrigation water efficiencies can be used to meet the growing demands in the domestic and industrial sector.

1.2 Objectives

This study aims to assess the effects of modern irrigation methods and modernized urban water supply networks on the water balance. The goal is to show how much water can be saved or be given to other sectors in order to reduce the current water balance

deficit. Different scenarios to quantify the water saving potential will be applied under the perspective of WDM. The focus is set on irrigation and urban WDM, with industry playing a minor role in the water balance. The evaluation will be based on literature review, interviews, and results on water saving through different water demand scenarios. The outcome should be a clear picture that can be used by decision makers to urge the need for a policy change towards further strengthening of WDM.

1.3 The IWRM Perspective

IWRM has become the standard guideline in the water sector. It is understood here as a holistic concept as adopted by the Global Water Partnership's definition: "*a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems*". Holistic implies the adoption of the watershed perspective in addition to include all relevant factors of the natural, economic and socio-political system.

This study uses WDM as one part of the holistic IWRM concept to shed light on the agricultural and domestic sector, in order to deliver a solid base on crucial aspects that need to be considered for strategic decision-making at the policy level in line with IWRM principles. The author is very well aware that such a policy decision cannot be based on considering WDM alone. However, a sound analysis of potential savings in the agricultural and domestic sector is pivotal for any successful future water management policy.

1.4 Challenge of Data

Difficulties arise in a lack of reliable data. Discrepancies exist among the ministries in their own estimates on water resources, which are again differing from estimates done

by other institutions as the Food Agricultural Organization (FAO) or the World Bank (WB). One reason is the lack of critical information, as the amount of renewable resources and the uncontrolled “on-demand” source of groundwater for irrigation (Salman, 2003). The same divergences exist on estimates on the volume of household water or unaccounted for water (UFW) (Elhadj, 2004).

The following challenges in data acquisition and data reliability were faced in this study. The data were requested from two ministries, the Ministry of Irrigation (MOI) and the Ministry of Agriculture and Agrarian Reform (MAAR). For this study it was only possible to acquire data from the MAAR about crop water requirements and area, which were used to calculate the irrigation water demand for the Damascus Basin. Hydrologic data from the MOI could not be obtained, as the information was not directly related to the project. In the irrigation sector, no data on the actual water usage exists, due to the lack of metering and the high number of illegal wells. In the domestic sector high uncertainty lies in the population figure itself, informal water connections, meter malfunction, etc. Domestic water demand figures range from 270 to 390 MCM in the year 2003 including studies from the WB, FAO and the MOI. More recent studies from JICA (2007) and SMBH (2008) have estimated a water demand for 2010 of 419 and 394 MCM, respectively.

2 Previous Studies

2.1 Agricultural Sector Description

Agriculture is the largest consumer of water and therefore constitutes the focus of this study. Today, on a national scale the agricultural sector contributes 24% to the total gross domestic product (GDP), similar to the industry sector (mining and manufacturing). It employs 20% of the total labor force and directly affects about 60% of the rural population (NAPC, 2008). Until the mid-80s the agricultural sector accounted for the largest share of GDP being supported through the five-year development plans, issued by the government. The goal of self-sufficiency in food was formulated for the first time in the fourth five-year plan (1976-80) after an increase in food imports in the late 70s (Collelo, 1987). This stimulated a doubling of irrigated land from 652 000 in 1985 to 1 356 000 ha in 2008, 25% of all cultivated land (MAAR, 2010). Further stimulation was given through government policies that supported wheat prices, which have been higher than the world price for several years, and the subsidized energy costs that proved to be strong incentive for famers on using more groundwater for irrigation (Salman, 2003).

Inevitably this led to an increase in water demand on surface and groundwater of 6.31 BCM from 1992-2000 totaling to 14.6 BCM in 2004 (NAPC, 2007). Groundwater abstraction alone increased from 30% in the 70s (Haddad et al., 2008) to almost 70% today. In total the agricultural sector consumes 88% of the total available water resources (Rabboh, 2007).

The Damascus Basin embodies about 6% of the nationally irrigated area with 75 400 ha and thereby does not compete as a strategic role on the national level. In total the agricultural used area in the basin is about 164 029 ha with 65% cultivated under

rainfed conditions in 2005-06 (Agricultural Statistics, MAAR, 2006). Today, about 70%, (53 000 ha) of the irrigated area relies on groundwater, while the remaining 30% rely on surface water for irrigation (SMBH, 2008). The result of the extensive groundwater use is a continuous drop of the groundwater level, the drying up of spring flows, and water quality degradation (Salman, 2003).

The average farm size in the Ghouta is 1.62 ha (Varela, 2001). The cropping pattern in the north and northwest is dominated by perennial crops due to the cooler climate along the mountains and the available springs. Whereas in the drier areas in the south and southwest both perennial and non-perennial crops are cultivated.

In the year 2002, according to the MAAR, 12 000 ha have been equipped with drip and 2 000 ha with sprinkler irrigation techniques, combined equaling about 18% of the total irrigated area.

The area used for irrigated agriculture declined through the years from a maximum of 87 000 ha in 1973 (SSAb, 1973) to a minimum of 72 000 ha in 2007 (MAAR, 2010). That equals a reduction of 15 000 ha, or a rate of 600 ha per year. This area reduction resulted from the conversion of agricultural used land to urban developments in the past 25 years (see Figure 1). Nevertheless, the decrease of cultivated land had no positive effect on the water balance. The reduced demand was equally consumed by the newly created water demand in the domestic sector. (Elhadj, 2004).

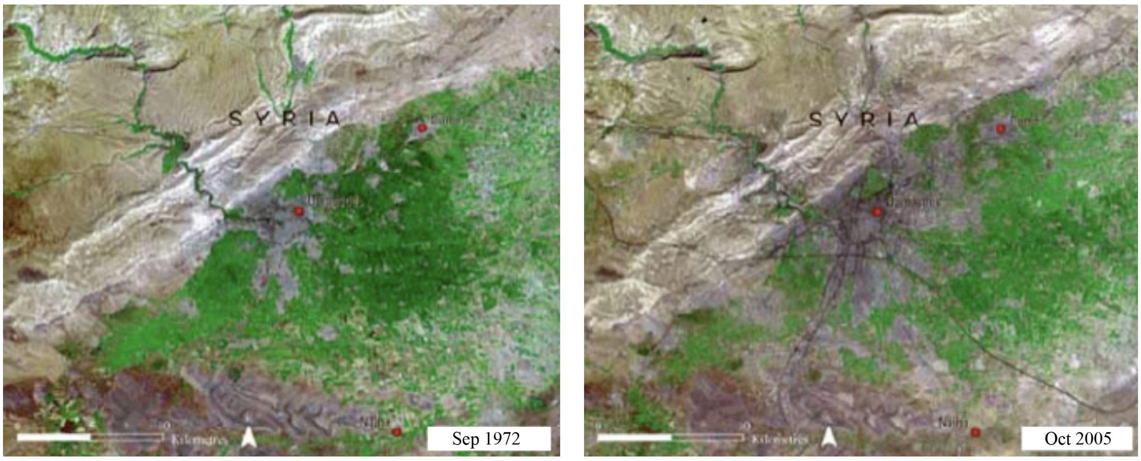

Figure 1: Satellite picture of urban dwelling (grey) between 1972 and 2005 (JICA, 2007).

2.1.1 Government Strategies and Policies in the Agricultural Sector

Historic View on Agricultural Strategy and Policies

Factors that shaped the agricultural strategy and policies of Syria since independence in 1946 were the land reform and external political environment of the 1950s and 1960s. The political environment was influenced by international alliances dictated by the cold war, insecurities by the Middle East developments, and the uncertainties inherent in the international trade system. Socialism, as the driving development paradigm during that time, was defined through state-led import instead of industrialization (Sarris, 2001). Central development planning started in 1960, with the issue of the first five-year plan, a practice that is ongoing until today.

With Hafez al-Assad taking power in 1970 socialism was redefined by increasing industrial employment, expansion of the role of the public sector, and at the same time an activation of the private sector. Already in those years economic development and self-reliance represented the key to national strength. The Syrian agricultural driven economy was meant to end by shifting towards a mainly industrial one. The lack of

local technical capabilities was compensated through importing complete prepared projects, financed through oil sales and Arab aid (Sarris, 2001).

The consequences from this development strategy were (Sarris, 2001):

I. Strategy of self-sufficiency in major food staples was adopted

II. State controlled production and trade

III. Foreign trade was almost a complete state monopoly

IV. Establishment of publicly owned food and agro-processing plants

Policies aimed to support the agricultural sector through price mechanisms for strategic crops and infrastructure investments by building roads, irrigation networks and land reclamation. The production, pricing and marketing of the so-called “strategic crops” (such as wheat, barley, cotton, sugar beet, tobacco, lentil, and chickpea) was centrally planned and government controlled. Today this control has been gradually relaxed with only wheat, cotton and sugar beet remaining in the centralized planning system. The agricultural production plan is set annually by the Supreme Agricultural Council (SAC) and is being implemented through the MAAR. The SAC is headed by the prime minister and has members from the major water related ministries, the leading political party and the head of the Famers’ Union (Sarris, 2001).

The ongoing national shift to a social market economy brought an increasing exposure and dependence to international markets. The government of Syria thereby is progressively giving up the centrally planned economic system and pricing mechanisms, which is exhibited through reforms in the economic and agricultural policies (NAPC, 2009c). In May 2010) Syria is attempting to join the World Trade Organization (WTO) and was granted observer status in 2010 (Freedman, 2010),

besides already signed trade agreements such as Great Arab Free Trade Area (GAFTA) or the Syrian-European association (NAPC, 2006).

Current View on Agricultural Strategies

Strategies embody both a vision of what a sector should look like and a conceptual road map showing how to fulfill that vision (De Benedictis, 2000).

Sectoral strategies are directed towards the overall global objectives like the general socio-economic objectives, such as economic growth, equity, stability, etc. They are not a detailed blueprint to be pursued, but rather to be seen as on how set priorities among sets of policies and institutions.

In the case of Syria, with a central role assigned to the State in directing both the allocation of resources and the distribution of the agricultural output De Benedictis (2000) used three categories of instruments for the pursuit of objectives: (i) institutional framework, (ii) planning mechanism, and (iii) set of agricultural policies.

The success of a sectoral strategy depends on three fundamental pre-requirements: (I) Government's capacity to ensure a stable macroeconomic environment for decision-makers, both public and private; (II) Government strategic decision on market and state instruments to achieve the coordination of resource allocation to produce growth; and (III) Government's strategic decision on market and state instruments to achieve the objective of distributive equity (De Benedictis, 2000).

The most recent assessment of the current situation of Syrian agriculture was done by the National Agricultural Policy Center (NAPC) in 2006. The study resulted in the following set of long-term sectoral objectives:

I. Increase of the agricultural growth rate and improvement of the agricultural producers' income

II. Optimizing the use and conservation of natural resources

III. Meeting the domestic demand for main food staples (wheat, legumes, etc.)

IV. Providing domestic processing plants with raw materials in sufficient quantities and appropriate quality

V. Improving rural infrastructure and services and developing local and traditional industries

VI. Attracting and enhancing national, arab and international investments in agriculture and related industries

VII. Developing and modernizing agricultural regulations to ensure optimal use of agricultural produce

VIII. Supporting and improving agricultural processing and marketing with the aim of enhancing accrued value added and valorizing comparative advantages

Current View on Agricultural Policies

The gradual move from the centrally planned five-year plans towards indicative planning was started through a process of decentralization with the 6th five-year plan (1986-1990). The government kept the state distribution system but for the first time started to let the private sector play a role in agricultural production and marketing (Sarris, 2001). In addition, the cost of support to agriculture made it more and more difficult to pursue earlier policies, as food self-sufficiency, over the long term (Varela-Ortega, 2003). Nevertheless, the government policy expressed in the 9th five-year-plan (2001-2005) was still orientated to achieve food security, irrespective to the greater water demand and thereby increasing the current water deficit (Rabboh, 2007).

But the overall change in the direction of policies at the same time reflects an increasing concern for the sustainability of the environment. Constraints in production showed the necessity for efficient use of scarce water resources. In the Ghouta area some farmers were naturally forced to switch to modern irrigation methods as their wells provided them with less water over time.

At present, water policies in Syria are designed to combine the expansion of irrigation from surface water and the reduction of irrigation from groundwater resources. At the same time, to achieve a sustainable use of water, an increase in technical efficiency and a reduction in future consumption is intended. Two of the pillars of this policy are the adoption of modern irrigation technologies at farm level and the substitution of water-intensive crops (Alabdullah, 2010).

2.1.2 The National Environmental Action Plan (NEAP)

In 2003 the Ministry of State for Environmental Affairs with support of the WB and UNDP prepared the National Environmental Action Plan (NEAP). It has similar goals as the NPCMI with it's core objective of:

> *"Incorporating environmental aspects in policies, plans and national programs, and protecting natural resources, biodiversity, cultural heritage, public health, and promoting the use of clean and renewable energies in the framework of sustainable development."*

The NEAP includes specific mechanisms and measures to achieve the stated objectives by 2015 with its progress monitored through performance indicators. Regarding the water sector the following policy priorities are given (listed in the order of importance):

I. Supplying drinking water

II. Developing industry and tourism

III. Promoting modern irrigation practices in agriculture

The strategic priorities in the NEAP were classified in four groups:

- Sustainable Use of Water Resources
- Sustainable Use of Land Resources
- Improvement in Services and Infrastructure of Urban Centers
- Sustainable Development of Natural Resources and Cultural Heritage

For the sustainable use of water resources the following short and medium term actions, to be reviewed by the responsible ministries are proposed:

- Match policy development planning to availability of water resources
- Stop the over-exploitation of water resources; maintaining sustainable use levels; and stop the intrusion of saline water into coastal aquifers
- Provide rural areas with potable water
- Reduce the contamination of water resources from domestic and industrial wastewater discharges

They include policy and institutional development, investment programs, and training and information measures.

2.1.3 National Plan for Irrigation Modernization (NPCMI)

In 2000, the government started a first program to support modern irrigation techniques nationwide through subventions with the goal to update the complete irrigated area with modern techniques until 2005. At the end of 2004, the converted area was 188 000 ha,

or 18% of the total irrigated area with an average growth rate of modernization of 29.7% per year (NAPC, 2006).

The goal was not reached for different reasons such as (NAPC, 2007):

- Farmers resisted the complex application process for the subventions
- High interest rate creating a financial burden on the farmer
- Farmers don't always own official papers for their land due to the inherit system
- Tradition and religious beliefs towards loans from banks

Due to the difficulties the program faced, the rising awareness about the limited water resources and the reoccurring droughts in the last decade, the Syrian Government started a new 10-year project about the conversion to modern irrigation methods in 2006. It is called National Project for Conversion to Modern Irrigation (NPCMI) and is based on the experiences from the first program including all made recommendations to speed up the modernization process. Attention was given to rationalization of water use and efficiency improvement. It aligns with the national environmental strategy aiming at ensuring water sustainability and conservation from depletion (MSEA, 2003).

The basis of the NPCMI is the joint memorandum by the MOI and MAAR from March 1, 2005, which was ratified by the cabinet as Presidential Resolution No 31 on 06/11/2005. It included the establishment of the Directorate of the National Project for Conversion to Modern Irrigation (NPCMI) under the MAAR with local branches on a governorate level. It is based on the Legislative Decree No. 91 issued on 29/09/2005 by the President of the Republic. The directorate is to promote the conversion process through financial, technical, and supervising actions. Therefore it The NPCMI directorate is presiding over the national fund for financing the conversion to modern

irrigation with a total capital of SYP 52 billion (820 Mio €, with 1 EUR = 63.75 SYP, as of 14.11.10) to be spend over the next ten years. The credit terms and conditions are stated in the MAAR decision No. 47/t dated on the 26/02/2006 (NAPC, 2009b).

According to the MAAR the project is described as follows (MAAR Brochure, 2010):

Applying the national strategy aiming at ensuring water sustainability and conservation from depletion and pollution includes the following policies and measures:

- Applying integrated water resources management based on demand management (striking balance between supply and demand)
- Giving attention to the environmental dimension to ensure water quality for various uses: household, industry, agriculture, etc.
- Ensuring food security sustainability

To attain those objectives the MAAR is focusing on the following issues: water efficiency improvement and rationalization, adoption of modern irrigation technologies that comply with the socio-economic condition, cropping structure, soil, hydrological conditions, holding size and effective participatory water management. The box on the following page summarizes the project in the perspective of the MAAR.

Actions taken by the MAAR up to today:

- Issuance of the water legislation under law No. 31 of 2005
- Establishment of the NPCMI directorate and fund under the legislative decree No. 91 of 2005
- Accreditation of 43 local companies and 16 agents for Arab and foreign companies to provide irrigation networks to farmers according to the standard specification of the project. The accreditation is still open for more companies

The Economic Return of the project

- Saving of 3550% of water compared to traditional irrigation methods
- Saving of energy costs used for pumping
- Decreasing cost of production and increasing land unit productivity
- Improving production quality and consequently improving farmers' annual income and living standard

Project Beneficiaries

- Farmers in irrigated agricultural land, particularly lands irrigated from groundwater and public irrigation schemes
- Small farmers who cannot afford the installation of modern irrigation systems
- Irrigated agricultural lands of farmer cooperatives and water user associations
- Areas planted for crops compatible with modern irrigation methods

Projected Outcomes

- Decrease of the current water deficit of 3.1 BCM by 2.8 to 4 BCM
- Conservation of irrigated agricultural land and reducing dependency on rainfed cultivation

Ensuring rural population settlement and provision of sufficient food leading to a better life.

The financial support for the farmer to buy new techniques has been changed compared the first project. According to Ahmad Fateh Al Kadri, director of the newly established NPCMI department two possible options exist to acquire a national grant that pays part of the conversion costs of switching from traditional to modern irrigation techniques:

1. 50% coverage of the state, if the farmer takes a loan with a 20-year payback period
2. 40% coverage of the state, if the farmer doesn’t take a loan and pays the cost directly by himself

This set up promotes the use of a loan and thereby control of the conversion process by the state, but also compensates rich farmers to apply for conversion. The loans are linked to training programs that assist the farmer on technical questions in switching to modern irrigation methods.

The implementation is organized through branches in all governorates. Priority areas are chosen according to the used water resources with a high priority on areas irrigated by groundwater and from public irrigation schemes and by its water balance. The potential beneficiaries will be assessed prioritizing small and poor farmers and areas that are technically and according to their cropping pattern more suitable (NAPC, 2009c).

According to Dr. Jamil Falouh, Director of the Water Resources Department of the MOI, the implementation plan for the project in the Damascus Basin will be finalized at the end of 2010, starting with the actual conversion in the beginning of 2011.

2.2 Domestic Sector Description

The city of Damascus was well known for its richness in water. The tradition of gardens and orchards is one of the oldest of mankind. The word “Damascus” originates from Aramaic and means “a well-watered place“. Villas and gardens were situated along the

Barada River that ran through the city and originates from the Ain Figeh spring. Though accompanied with the rise and growth of the city the demand of water was rising simultaneously. More people needed more water to drink and more food to eat. Agriculture and the people were supplied with water as much as they needed. This way of water management lies in stark contrast of today's idea of WDM. Savenije & van der Zaag (2002) define WDM as *"the development and implementation of strategies aimed at influencing demand, so as to achieve effective and sustainable use of a scarce resource"*.

The term water demand is understood as the quantity of water that has to be supplied to satisfy the requirements of household use, commerce, institutional facilities, industries and technical losses of the network itself. The following section is about demand management in a way of reducing the demand per capita and the reduction of UFW. A scenario combining both elements and estimating the total domestic water demand is given.

2.2.1 Institutional Setup, Regulation, Policies and Reform

The responsibility of water supply on a national level belongs to the Ministry of Housing and Construction (MOHC). At governorate level public entities under the supervision of MOHC are responsible for it. Financially DAWSSA is in theory independent but depends on subsidies from the Central Government for covering the shortage of its operation and maintenance budget.

In the Damascus Metropolitan Area the water supply is managed by DAWSSA. It is the new name resulting from the recent merger of the two former entities for each governorate of Damascus and Rural Damascus. The steady growth of the city and its surroundings formed it to one metropolitan area today.

DAWSSA has divided Greater Damascus into 40 water economic units (WEU) – supply subunits that are responsible for their individual operation and maintenance. They do metering, customer service, network reparations and the collection of fees autonomously. Some of the directly surrounding WEUs of Damascus are already connected to the city network, which is supplied with good quality Figeh Spring water. But most of the WEUs are independent with own resources and sewage treatment. The supply coverage is estimated by DAWSSA to reach nearly 100%, with recognition that at least 1 800 families are illegally connected (RECS, 2007). It has to be noted, that the domestic water demand is difficult to estimate. The only reliable data in the calculation of the domestic water demand is the Damascus City water production. Water production figures in Rural Damascus are based on estimations of the combined well production rates. The water consumption values are based on demographic estimates and field surveys.

Regulatory Design

The regulatory design in Syria has been studied by Gerlach (2010) and is shortly summarized in the following section. Regulation is meant as a set of functions and competencies, such as setting, monitoring and enforcing basic rules such as performance standards, setting and reviewing tariffs, and resolving complaints and disputes. Those functions are shared among several institutions in Syria. The legal mandate is not well defined and overshadowed by political interests and centralized power. The MOHC could be described as a regulator, but lacks power and ultimately has to report to the State Planning Commission (SPC) on a quarterly basis, from where final decisions are approved (see Section 3.1). In the context of the MOHC as a future regulator, the dominance of technical/engineering staff has a negative impact on the

internal capacity to perform needed functions, such as commercial and their socio-economic implications.

Policies

Policies concerning drinking water and wastewater defined in the tenth Five-Year Plan from 2006-2010 are summarized in this section. The long term objectives are aiming at IWRM principles such as demand management and the involvement of all stakeholders in project work. In that perspective the policies are similar to the policies in the agricultural sector. The long term key objectives are listed in the following (GTZ, 2007):

- Sustainable management of water resources designated for drinking purposes which ensures safe and clean drinking water for current and future generations
- WDM via combination of technology, awareness and economic incentives
- Cost recovery for operation and maintenance for drinking water supply and sewage services
- Cooperation with the private sector in the performance of tasks which increase the technical and financial effectiveness of the establishments
- Decisions based on socio-economic appraisals and environmental impact assessments
- The participation and communication with all stakeholders for drinking water supply and sewage projects which ensures that the optimum services are provided to all segments of society

Reform processes

The current five-year plan sets the direction for institutional restructuring and identifies current problems, such as centralized decision-making, overlapping responsibilities among institutions, as well as budget deficits. It creates a framework for private sector participation, which is for now concentrated on wastewater treatment plants. The

institutional restructuring, as actively supported by the GTZ, sets the MOHC as the sector supervisor and regulator with direct responsibility for service provision delegated independently managed WEUs. Other forthcoming activities are financial sector modeling with the Ministry of Finance on cost recovery and to create a corporatization environment in the WEUs by strengthening their autonomy on internal control and inspection, public information systems and professional networking (Gerlach, 2010).

2.3 Other Relevant Studies

General information on ground- and surface water of the Damascus Basin is provided by Wolfart (1963), Burdon (1964), Lamoreaux (1989), and Kattan (1997 and 2006). The geology and hydrogeology of the Basin, the groundwater chemistry based on isotope studies as well as conditions for water extraction and the water balance are described.

Detailed Studies on the water balance have been done by the Union of Soviet Socialist Republics (USSR), the Japan International Cooperation Agency (JICA) and the SMBH Sdn Bhd Consulting Engineers (SMBH). The USSR (1986) Study has done extensive hydrological field work and laid the basis for future studies. A review about the USSR and JICA studies is given by SMBH, including scenarios and an outlook on the future water balance.

The technical corporation of the German Federal Institute of Geosciences and Natural Resources (BGR) and the Arab Centre for the Studies of Arid Zones and Dry Lands (ACSAD) did many studies on "Management, Protection and Sustainable Use of Groundwater and Soil Resources in the Arab Region". Information about the study area were given by Hobler and Rajab (2002) "Groundwater Vulnerability and Hazards to

Groundwater in the Damascus Ghouta" and Margane (2003) "Guideline for Sustainable Groundwater Resource Management".

Studies on WDM in Syria and the Damascus Basin include those of Rabboh (2007), Bazza and Najib (2003), Salman (2008), and Yassin (2005). Rabboh gives an overview about the current status and implementation of WDM in general. Salman shows different possible ways on how to manage water demand in the agricultural sector. The other studies give examples on how to adapt WDM from small to large-scale applications.

A good overview on the water sector as a whole and the water policy is given in several studies including Edwards-Jones (2001), United Nations Economic and Social Commission for Western Asia (UN-ESCWA, 2003), German Technical Cooperation (GTZ, 2004) and Food and Agricultural Organization (FAO, 2003). Information on current policy and practice that have a negative impact on the environment is given. As well as suggestions for developing policy, which could have a beneficial impact on the environment, are made. Policy objectives are including food production, equity and efficiency.

The most comprehensive studies on irrigation techniques have been done by the World Bank (WB, 2001), FAO in cooperation with the Ministry of Agriculture and Agrarian Reform (FAO-MAAR, 2001), and Wattenbach (2006). Scenarios of government policies on modernizing irrigation systems and the expansion of agricultural land are discussed. Several Studies by the National Agricultural Policy Center (NAPC) are dealing with the current use of irrigation techniques, their of water efficiency and economic impact on the farmer.

Urban WDM is described by RECS International Inc. (RECS, 2007), Consulting Engineering Salzgitter (CES) and GFA Consulting Group (CES and GFA, 2008). RECS has conducted a comprehensive study on “Urban Planning for Sustainable Development” assessing the current domestic water demand and scenarios for the future demand. Technical solutions for securing the growing domestic demand are given. The CES and GFA study focuses on decentralization of wastewater treatment and the detailed assessment of water use in sample areas of Rural Damascus.

3 Institutional, Legal, and Economic Aspects

3.1 General Water Sector Description

The institutional setup of the water sector in Syria is hierarchically organized. It is headed by the Supreme Agricultural Council (SAC) with a number of ministries and organizational structures sharing the responsibilities of water resources management. Each Ministry has local bodies distributed over the 14 governorates, such as local directorates or local institutions that are related to the central body of each Ministry (Aquastat, 2008). It has to be noted that there is also a "private institutional area" in water management such as private user associations, private operators of water infrastructure and specialized consulting firms, NGOs, etc. (GTZ, 2004). In the following section a short description of the key institutions involved in the water sector is given.

Higher Water Council (HWC)

The HWC was established in 2007 with its main responsibilities concerning the development of water strategies, water planning and policy formulation and to manage transboundary water issues. Another task is to coordinate between the relevant ministries on assessing drinking water sources and the utilization of treated wastewater (MSEA, 2003).

Supreme Agricultural Council (SAC)

The SAC was established in 1975, representing the highest authority responsible for agricultural policies and planning. It is headed by the Prime Minister, with members from the major water related ministries, the leading political party, and the head of the Farmer' Union, ensuring that all perspectives and stakeholders are represented (WB,

2001). The council has parallel councils in the governorates headed by the governor. The SAC is the only central authority with the right to approve the annual production plan for agriculture. The MAAR thereby acts as a secretariat for the SAC responsible for the execution of its resolutions and decisions (Sarris, 2001).

Ministry of Irrigation (MOI)

The MOI is the main actor for the management of water resources and is the single authority responsible for the allocation of water resources to all sectors. Besides it organizes the planning, design, management, operation and maintenance of dams and public irrigation schemes. It is also responsible for controlling drilled wells licensing new wells. The MOI was reorganized according to the new integrated and demand driven approach formulated in the new water legislation in 2005 to better cope with the water scarcity (GTZ, 2004).

As a central body of the MOI there is the General Commission for Water Resources (GCWR), which is responsible for the integrated water management approach and is in control of the Water Resources Information Center (WRIC) with directorates in all river basins (INECO, 2009).

Ministry of Agriculture and Agrarian Reform (MAAR)

The MAAR is responsible in formulating and implementing the annual agricultural development plan and public interventions related to the production, regulation, and distribution of agricultural goods and activities (GTZ, 2004). It regulates and rationalizes the use of water for agricultural purposes. It is also responsible for the recent NPCMI project that started in 2006 (see Section 2.1.3) including to encourage farmers in designing, implementing and carrying maintenance works of on-farm irrigation systems.

The Agricultural Cooperative Bank (ACB) as a central body of the MAAR is the only formal source of credit for Syrian Farmers (NAPCa, 2009). It is not a bank in a conventional bank, but ensures the provision of credit to support the implementation of the Annual Agricultural Plan. It also is responsible for marketing, as the only official buyer of today's strategic crops wheat, cotton and tobacco (IFAD, 2007).

Another central body is the Directorate of Agricultural Extension Units (DAE), with branches on the governorate level, its supporting units (SU) established in 2006 being responsible over 1200 Agricultural Extension Units (AEU) that are distributed over the country on a village-level. The AEUs are assessing the irrigated area, irrigation technique, number of wells and its GW levels, type of crop, number of fruit trees, number of livestock, and production figures. AEUs are also responsible for disease surveillance and prevention and carrying out statistical surveys and field trials (NAPC, 2003). All collected information is given to the responsible SU in quarterly meetings. AEUs are directly supporting the farmer through knowledge transfer and acting as a direct contact to the farmer. The SU is responsible for implementation and monitoring of the annual Agricultural Plan. The Agricultural Plan is issued by a Committee set up with representatives of the MOI, MOA and the Farmer Union (NAPC, 2003).

It is also embodies the General Commission for Scientific Agricultural Research (GCSAR), conducting nationwide research on crop water requirements, land resources, on-farm water management and irrigation methods and technologies.

Ministry of Housing and Construction (MOHC)

The MOHC established in 2003, is responsible technically for the domestic drinking water supply by building, operating and investing in water networks and relevant water facilities and strategically by developing regulations and policies (GTZ, 2004). It is

supervising fourteen Water Establishments, one for each governorate. Inside the MOHC is the Directorate of Sewerage that is responsible for sewerage management by designing treatment plants, sewer networks or approving plans prepared by other organizations and supervision of construction projects (AHT-Group, 2009).

Ministry of Local Administration and Environment (MLAE)

The MLEA, established in 2003, is responsible for monitoring and controlling water quality through laboratories and observation networks. It is issuing standards for the protection of water resources and is tracking the source of pollution to comply with the environmental law (AHT-Group, 2009). It also includes a directorate for sewer networks and treatment plants overseeing sewage collection in areas, where no sewage companies are operating (GTZ, 2007).

Farmers' Union (FU)

The FU or Peasant Union was established in 1974, merged out of then several different Cooperative Unions (UNDP, 2009). They are affiliated with the MAAR with its main responsibility to advice farmers on all agriculture related issues. They are responsible for digging wells, canals and constructing small dams for irrigation and livestock. Though farmers are also constructing wells on their own (GTZ, 2004).

The FU with a strong grip on about 900 000 members is well represented in high-level policy making and implementation level. It provides a significant opportunity for the development of a participatory water management approach (Salman, 2004).

State Planning Commission (SPC)

The Directorate of Integrated Water Resources Management (DIWRM) at the SPC is responsible for coordination, strategic planning, monitoring and evaluation of the water

sector performance in Syria (IDRC, 2009). At the same time it assumes the role for the investment planning and budgeting process, with direct working relation to the Planning Directorate of each ministry.

This means the investment planning and budgeting process of the SPC is organized along institutional and not sectoral lines and thereby not meeting the challenges of a coordinated water sector reform among the involved institutions (GTZ, 2004).

Ministry of Industry (MOIND)

The MOIND plays an indirect role, with no department involved in water management issues. The Directorate of Scientific and Technical Affairs is issuing licenses for new industrial projects but is restricted to encouraging industries to optimize their water use and the construction of wastewater treatment plants (GTZ, 2004).

3.2 Legal Framework

Until 2005 there was no special water law existing, only water related decrees and decisions from ministries directed at water management and the environmental law could be distinguished.

The Environmental Law no. 50, passed by President Bashar Al-Assad in 2002, entitled the General Commission for Environmental Affaires (GCEA) to set policies, monitor and penalize in order to protect the environment against pollution. The law states that industry is obliged to treat their wastewater before the discharge into rivers, direct irrigation or discharge into the sewage system (AHT, 2009). However, the law lacks concrete provisions concerning water management and quality control (GTZ, 2004). A detailed description can be found in the EIA Final Report.

In 2005 a new water legislation (Law No. 31) was issued. It comprises of WDM approaches on the national level and the use of water resources by avoiding groundwater depletion. The focus is on supporting the transfer to modern irrigation methods (see section 2.1.3), controlling licenses to drill wells and the use of groundwater, and the support of the participatory approach to water management through the establishment of Water User Associations (WUA) (AHT-Group, 2009). It also addresses the protection of public water from pollution and the use of wastewater for irrigation and defines punishments for any violation.

The public ownership of water is defined in law No. 144 (1925) and the modalities and use of water abstraction in law No. 165 (1958). There the priorities were set considering drinking water the first priority, industry and tourism the second and agriculture the third priority (AHT-Group, 2009).

Water Rights

The Barada River irrigation scheme can be dated back to the first millennium B.C. with written sources mentioning extraordinary gardens and orchards of Damascus (Pitard, 1987). At that time rules of water distribution and management had existed making it one of the oldest and largest community irrigation systems in the world (SMBH, 2008). Due to the variable flow conditions and to overcome the problem of sharing the available water a hierarchical water rights system according to proportional sharing and distribution has been developed. It was dependent on the area to be irrigated by each particular canal. Each group of farmers along a canal own water rights that have been passed on from generation to generation.

Standards and Enforcement

In Syria the Syrian Arab Organization for Standardization and Metrology (SASMO), which is part of the Ministry of Industry, is the single organization that is authorized to issue standards. Few standards that are designed to protect the water resources exist and are listed in the following: Standard no. 2580 (2002) deals with industrial liquid wastes that are discharged into the public sewer system. The standard No. 2823 (1990) and 2752 (2003) deal with treated wastewater used for irrigation. Both standards are based on WHO standards. The standard No. 45 on drinking water was amended in 1994 and the Standard No. 2665 about the disposal of sewage sludge in 2002. The enforcement of these standards is under the responsibility of the relevant ministries, but no clear mechanism for enforcement does exist (GTZ, 2004).

3.3 Farmer Awareness and Capacity Building

Information exchange or outreach to the farmer is done through the AEUs on farm level. In the Ghouta Area are 59 AEUs, each responsible for three to four villages. They are subordinated to 13 Supporting Units in Rural Damascus, each being responsible for four to five AEUs. The SUs were established in 2006. Each SU has a subject matter specialist (SMS) on irrigation techniques. The units are staffed with agronomists, agricultural supervisors, veterinarians, and veterinary supervisors. The services provided to the farmer are free of charge and are centrally coordinated by the Extension Directorate of the MAAR in Damascus.

There are several forms of collective or individual interaction, which are chosen by the extensionists to achieve their desired goals, within the extension programs. They consist of (a) field, house and office visits, (b) extension lectures, (c) field days, (d) production

contests, (e) extension publications, (f) television, (g) radio, (h) movies, (j) moving agricultural theater, (k) foreign exhibitions and (i) museums (NAPC, 2002).

Official partner on the awareness level is JICA with the "Project for Development of Efficient Irrigation Techniques and Extension in Syria" (DEITEX) project that started Phase II in 2008 and lasts until 2012. The DEITEX Phase I Project in Rural Damascus Daraa ran from 2005 until 2008. Demonstration Farms were built to show good examples of modern irrigation systems and conducting training courses in cooperation with the AEUs. Extension activities on saving water were carried out by newly trained and skilled water extensionists (WE) and subject matter specialists (SMS). These water extensionists are now capable to conduct farm survey to identify farmer's problems regarding irrigation, to make diagnosis of irrigation system, to prepare extension materials such as posters and brochures, and to carry out extension activities such as field day, field visit, workshop and seminar. On the other hand, irrigation SMS is ready to work as a trainer of water extensionists in conducting training courses of modern irrigation (JICA, 2008).

3.4 Water Tariffs and Incentives

The water tariff in Syria is set by the MOHC after agreement with the Prime Ministry. The water establishment itself has in theory the right to determine tariff components but in practice can only propose it (Gerlach, 2010). In the current irrigation water tariff system the farmer pays 3500 SYP per hectare annually if connected to a public irrigation network or the use of groundwater. The costs can go down to SP 600 if irrigation is only used for winter cropping. The fees are based on the area regardless the volume of water the farmer uses. If the farmer himself extracts water from rivers or springs for irrigation, they do not have to pay any fees to the government. In the

Damascus Basin the government only collects fees from the licensed wells, which constitute only 21% of all wells, and irrigation schemes along the Barada and Awaj Rivers. Comparing the current water tariff per hectare to the energy costs of pumping groundwater from a depth of 100 to 150 m, which would be in the range of about 13 000 to 21 000 SYP ha a^{-1}, the energy cost recovery ranges between 17 and 27%. Out of the Annual Agricultural Statistics Abstract in 2001, the value of water for the production of irrigated crops per hectare varies between 4 to 18% of the total production costs. Though the estimated economic value of irrigated water per ha varies between 6 000 and 23 000 SP ha a^{-1} revealing a high potential for raising the tariff (World Bank, 2001). In the domestic sector the water tariff is based on volume consumed. The current tariff system is listed in Table 1.

Table 1: Water and wastewater tariff for Damascus.

User	Monthly Consumption (m^3/month)	Water Price (SYP/m^3)	Wastewater Surcharge (% of water price)	Amount for Wastewater (SYP/m^3)
Domestic	0-20	3.0	5	0.15
Domestic	20-30	4.5	10	0.45
Domestic	30-60	13.5	15	2.03
Domestic	>60	19.0	20	3.80
Governmental		8.5	55	4.66
Commercial, Industrial, Tourism		22.0	40	8.80

Source: (GTZ, 2004).

Compared to an international scale, households are paying up to 5% of their monthly income for water and sewerage services. In Syria with the current tariff structure the monthly charges amount to less than 1% even for the average and low-income households (GTZ, 2004).

Incentives on water saving

The current tariff based on the area and not on volume doesn't offer any incentive to the farmer to save water. On the contrary it leads to neglect and over irrigation of the fields. All in all, a readjustment of the current irrigation tariff system is required to guarantee the means of financing the required infrastructural needs. Volumetric pricing is ideal, but linked to high implementation costs. But in combination with the NPCMI project the possibility of installing meters with the new irrigation techniques and licensing of wells should be evaluated.

Another incentive for the farmer to save water could be a rewarding system. Thus some reward could be given to the farmer if he follows a sustainable cropping plan set by the State (FAO, 2001).

3.5 Deficits and Potentials of the Water Sector

Deficits

The main obstacles in the way of effective work are the overlapping responsibilities of many players in the water sector. This gives a fragmented picture holding inherent conflicts of interest, even within the institutions. They all make their own budgeting and decision-making, have a lack of autonomy and at the same time a lack of accountability of service providers. This can be exemplified through the following points (GTZ, 2007):

I. This framework makes it difficult to accomplish new strategies, such as the IWRM approach, which is included in the recent 10^{th} five-year plan, but depends on the collaboration of all related stakeholders. A national water master plan defining a long-term framework, as the basis for sustainable water sector development does not exist. The current policy on food security, which is linked to new land reclamation, conflicts with the policy aimed at the sustainable use of water resources.

II. Land use planning is done not always in coordination with the local water service provider, e.g. with new settlements in the Ghouta area, that are receiving water that is unsuitable for drinking purposes.

III. The national monitoring of water resources is undertaken through different governmental organizations. There is no open data exchange between the organizations, with holding the possibility of an integrated management.

IV. All water facilities for supply or sewage are public, with minor participation of the private sector and civil society. Up to now, the legal and institutional framework does not provide a fair environment for private businesses to enter the water sector.

V. The communication among managers and specialists in the Syrian water sector is not following systematic rules. The establishment of professional networks would improve the integrated future planning processes that are based on Syrian experiences.

VI. The coordination among the donors is weak and exists only on personal contacts within project contexts. There is no donor coordination committee, in order to improve the work efficiency or avoid, e.g. any duplication of measures. This has to be initiated and directed by the Syrian Government.

Potentials

The Syrian Water Sector is one of the priority sectors that require fundamental reform on a national level. The current 10th five-year plan demonstrates the efforts to reshape and improve water policy on a national level. The stated goal of sustainable water resources management and equitable access to drinking water shows the commitment and willingness of the Syrian government to achieve them. Moreover, efforts can be seen in the legal framework, such as the endorsement of the water and environmental law, legalizing the establishment of Water User Associations (WUAs) and introducing management boards with membership from key stakeholders (GTZ, 2007).

4 Study Area

4.1 Natural Conditions

4.1.1 Geography and Topography

The Damascus Basin, also known under the name of Barada and Awaj Basin is located in the southwestern part of Syria (Figure 2). The basin lies between 32°43’ and 33°55’ of latitude N and 35°48’ and 37°05’ of longitude E covering about 8 692 km^2 (Kattan, 2006). It is situated in the flat central part between two major geological structures, the Palmyrides-fold system in the north and west and the depression of Mt Arab in the south. The elevation in the mountain range is about 2000 m with elevations in the basin decreasing from 710 m at the foothill of Mt Qassyoun in the Damascus City area to 588 m in the plain at the Al-Hijaneh area (ACSAD-BGR, 2002).

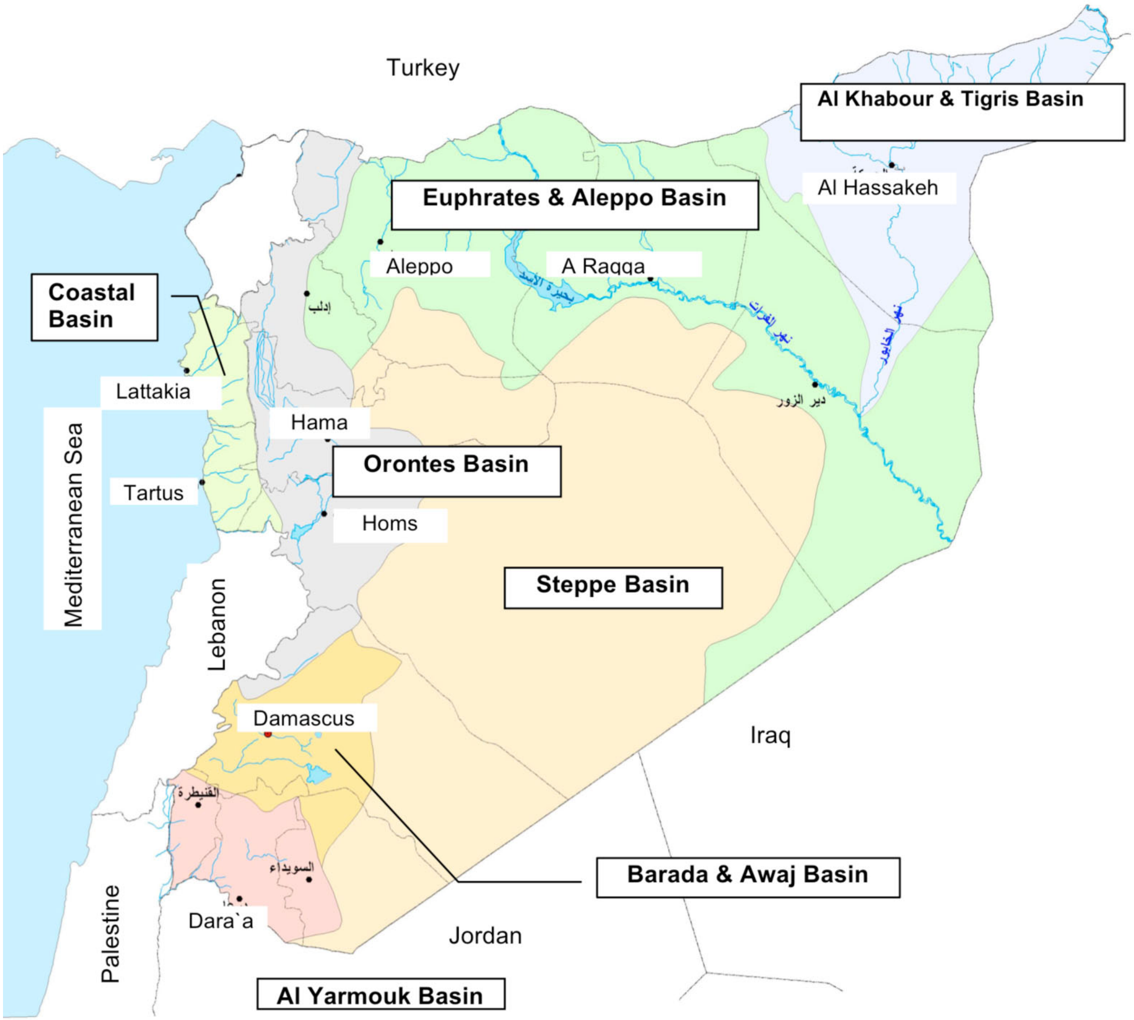

Figure 2: Hydrologic surface water basins of Syria (JICA, 2007).

4.1.2 Climate Data

According to the Köppen climate classification the Ghouta basin is categorized as Csa (C = warm temperate climate, s = dry summer, and a = hottest month above 22 °C and more than 4 months above 10 °C) or subtropical of Mediterranean type (ACSAD-BGR, 2002). It is characterized through hot and dry summers with rain falling in the mild winter. The rainy season lasts from October to April with the main rain falling from November to March reaching a peak in December and January. The average annual precipitation in the basin decreases gradually from east to west a maximum of about

250 mm at the foot of Mt Qassyoun to a minimum of 100 mm (Figure 3) (JICA, 1999). In the mountain range the mean annual precipitation is 548 mm (SMBH, 2007).

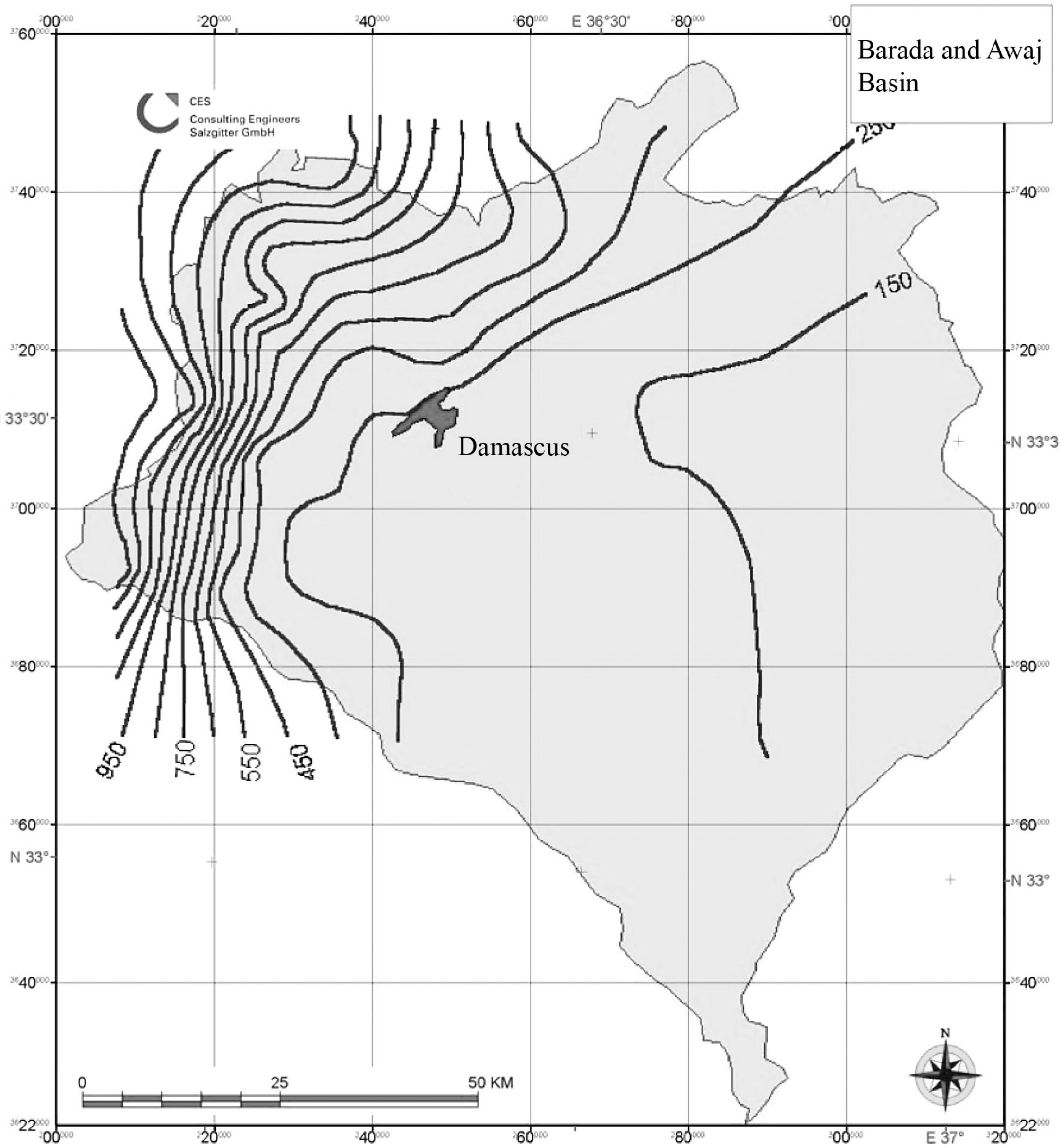

Figure 3: Average annual precipitation in the Damascus Basin (CES and GFA, 2008).

The yearly precipitation in the Damascus Basin is 270 mm and varied between 133 to 499 mm in the time period from 1989 to 2008 (MAAR, 2010).

The average yearly temperature ranges from a summer maximum of 25-27 °C to a winter minimum of 10-15 °C (JICA, 2001). At high-altitude areas (1500-2000 m) the temperature drops below 0 °C with accumulating snow cover. In the summer it reaches

up to 50 °C. Historically, looking at the Damascus precipitation measurements, droughts are occurring every 13 years with less than half of the average annual precipitation (UNDP, 2009). During the last decade they have been occurring more frequently with consecutive drought years from 1999-2001 and 2007-2009 (AGRECO, 2009).

The average potential evaporation and evapotranspiration reaches about 1800 and 1600 mm/a respectively. In the plain towards the east it can reach more than 2000 mm/a (JICA, 1997). The Ghouta basin can be described as arid to very arid after the Emberger classification (Emberger, 1955).

Climate Change

A look at the past shows that the average temperature over the Mediterranean area has increased by 1.5 to 4 °C in the last 100 years (IFI, 2009). The average precipitation showed a negative trend in the last 50 years. For the future the Intergovernmental Panel on Climate Change (IPCC) forecasts a temperature increase for the region of about 3 to 3.6 °C (IPCC, 2007) and a yearly decrease in precipitation of 5.1% at 2040.

Overall there is a tendency towards extreme events with drier and wetter years in the future. Also the drought frequency is predicted to be 10 times higher for the next 100 years (IFI, 2009).

4.1.3 Geology and Hydrogeology

The Damascus basin is situated on the northern slope of the Arabian shield (Wolfart, 1964). Between the in 2.1 mentioned Palmyrides-fold and the depression of Mt Arab it forms a geologic syncline filled with continental and lacustrine deposits and volcanic lavas (Kattan, 2006). The base of the depression is formed of Cretaceaous, Paleogene,

Miocene basalt, and Neogene rocks. The covering Quaternary deposits reach a maximum thickness of between 400 to 500 m. A geological map with a cross section is shown in Figure 4. During the Pleistocene, about 200 000 to 250 000 years ago, the depression was covered by a lake with an elevation of about 700 – 750 m.a.s.l. (ACSAD-BGR, 2002). For comparison, the Ateibeh Lake, which has dried up in recent years, is just below 600 m.a.s.l.

The Volcanic lavas originate in the Neogene period from the Jebel Al-Arab and Hauran area and covered large parts of the Damascus plain. The thickness and distribution varies within short distances depending on the topography of the given time period.

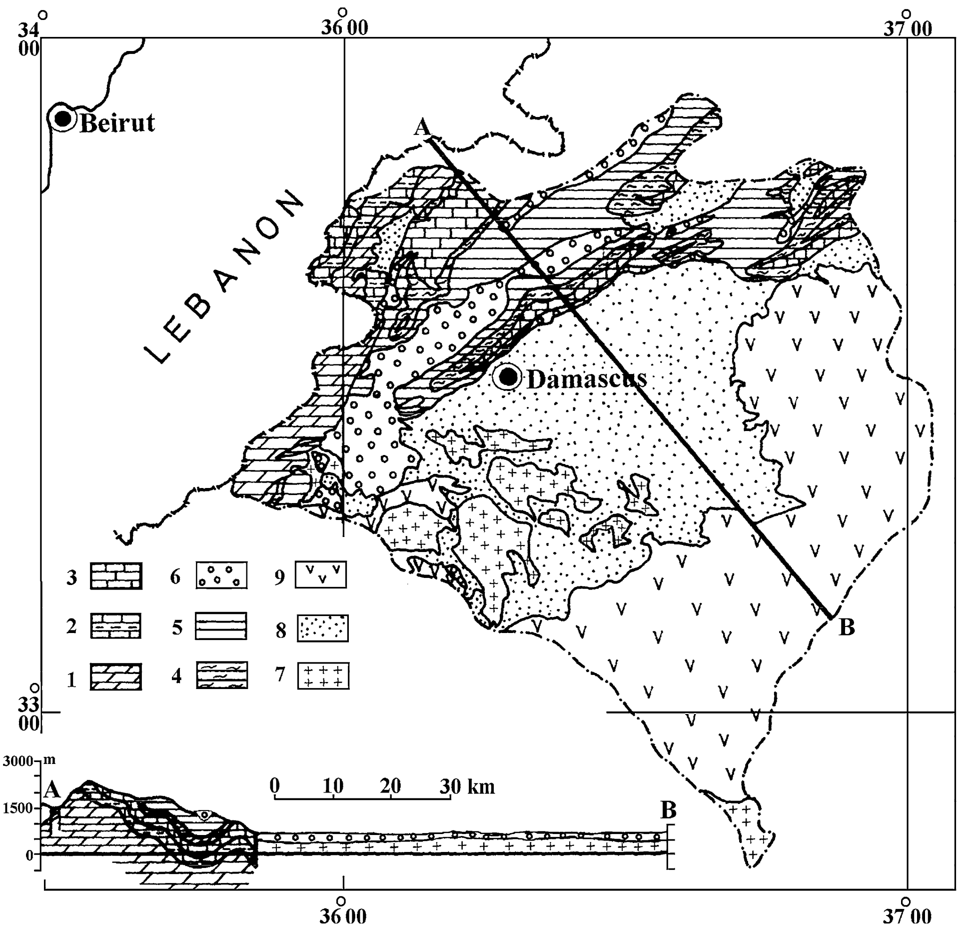

Figure 4: Geologic map and cross section of the Damascus Basin with 1: Jurassic; 2: Lower Cretaceous; 3: Cenomanian- Turonian; 4: Upper Cretaceous; 5: Paleogene; 6: Neogene; 7: Neogene basalt; 8: Quaternary; 9: Quaternary basalt (Kattan, 2006).

Hydrogeology

The hydrogeology in the Damascus basin is due to the prolonged sedimentation period and the resulting variety of stratigraphy, rather complex. The groundwater could belong to up to 14 different aquifers after Selkhozpromexport (1986). Hydraulic contact between all of these units is possible, especially in tectonic fracture zones (ACSAD-BGR, 2002).

For this study only 4 aquifers will be described, as they represent the uppermost exploitable aquifers:

- Upper Quaternary fluviatile deposits, including alluvial fans
- Upper Quaternary lacustrine deposits
- Neogene basalt
- Jurassic, Cretaceaous and Paleocene limestone deposits

The groundwater level varies from 2 m close to the Barada River to up to 70 m in the northeastern part of the study area (ACSAD-BGR, 2002).

Upper Quaternary fluviatile deposits, including alluvial fans

This is the most important aquifer for the domestic water supply of the settlements in Rural Damascus. Also most of the irrigation water is taken from this unit with more than 15 000 wells drilled in the Ghouta area.

The fluviatile deposits consist of poorly sorted pebble, gravel, loam and sandy clays. Lenses of clayey sand or pebble conglomerates with carbonate and clay cement with a thickness of 5-7 m can also be found. The maximum thickness is 100 m but generally varies between several meters to up to 40 m. It decreases in southerly to southwesterly direction. The upper part of 15 to 20 m is mostly made up of alluvial-proluvial materials

mainly in the form of loam and clays. The hydraulic conductivity varies strongly from 4 to 140 m d^{-1} with an average of 58 m d^{-1}. The transmissivity values are in between 130 and 3700 m^2 d^{-1} with an average of 1400 m^2 d^{-1} (JICA, 1997). With increasing clay content in the fluviatile deposits in the southwestern part, the productivity of wells is decreasing (ACSAD-BGR, 2002). The water quality is generally good, with total dissolved solids (TDS) of < 0.9 g L^{-1}. Though through the overexploitation and intensive use of fertilizer parts are not suited as drinking water with nitrate levels exceeding the national threshold (CES and GFA, 2008).

Upper Quaternary lacustrine deposits

In general it consists mainly of lacustrine clayey, marly deposits with a few beds of poorly sorted gravel and sand. Though, the consistency changes from the area around Al-Ateibeh and Al-Hijaneh lakes, where it is made up from loam and clay with a few beds of sand to the western and northern parts, where it is mostly composed of limestone and marl with beds of clays. The thickness reaches a maximum of more than 200 m in the area west of the Ateibe Lake and gradually decreases towards the north and south. The hydraulic conductivity ranges between 2 and 14 m d^{-1}, occasionally reaching 88 with a transmissivity of 39 to 1485 m^2 d^{-1}. The aquifer contains mostly brackish water with TDS of 1 - 4 g L^{-1}.

Neogene basalt and lava flows

The basalt and lava covers wide areas to the southeastern part of the study area, as can be seen on the geologic map (Figure 4). Towards the central part of the basin it dips under the alluvial deposits but underlies most of the basin. It consists of fissured basalts associated with thin beds of sand and sandstone. Individual lava layers have layers of clay and fine sand that appears to reduce the vertical permeability of this aquifer in

some areas. The thickness varies from a few tens of meters in the area of Jebel Abou Atreez to up to 200 m further north. The transmissivity value is about 30 to 60 $m^2\ d^{-1}$. The groundwater quality is rather fresh with TDS of 0.3 – 0.8 $g\ L^{-1}$ but becomes more saline in the Al-Ateibeh and Al-Hijaneh area.

Jurassic, Cretaceous and Paleocene limestone deposits

They crop out in the adjacent mountain ranges west and north of the city and underlie at depth in the basin. The consistency is mostly limestone with some conglomerates. Combined those aquifers form the major source for the Ain Figeh spring, which is the main source of drinking water for the city of Damascus. According to La-Moreaux et al. (1989) it is one of the most productive ones in the world. The groundwater divide between the study area and the Ain Figeh catchment is marked on the hydrogeological map, with groundwater east of the divide probably flowing into the Ghouta basin.

4.1.4 Hydrology

The study area includes springs, six main river systems (Figure 5) and two former lakes – Ateibeh and Hijaneh that have dried up in the course of growing water demand. Only the Barada and Awaj rivers are perennial, though without almost no flow during the summer when the water demand for irrigation and drinking water supply is high. All rivers are listed in the following table:

Table 2: List of the main river systems in the Damascus Basin.

River	Catchment Area	Type
Barada River	1531 km^2	perennial
Awaj River	254 km^2	perennial
Wadi Deneir	544 km^2	ephemeral
Wadi Liva	452 km^2	ephemeral
Wadi El Khanafes	337 km^2	ephemeral
Wadi Mdiyeh	214 km^2	ephemeral

Source: (SMHB, 2008).

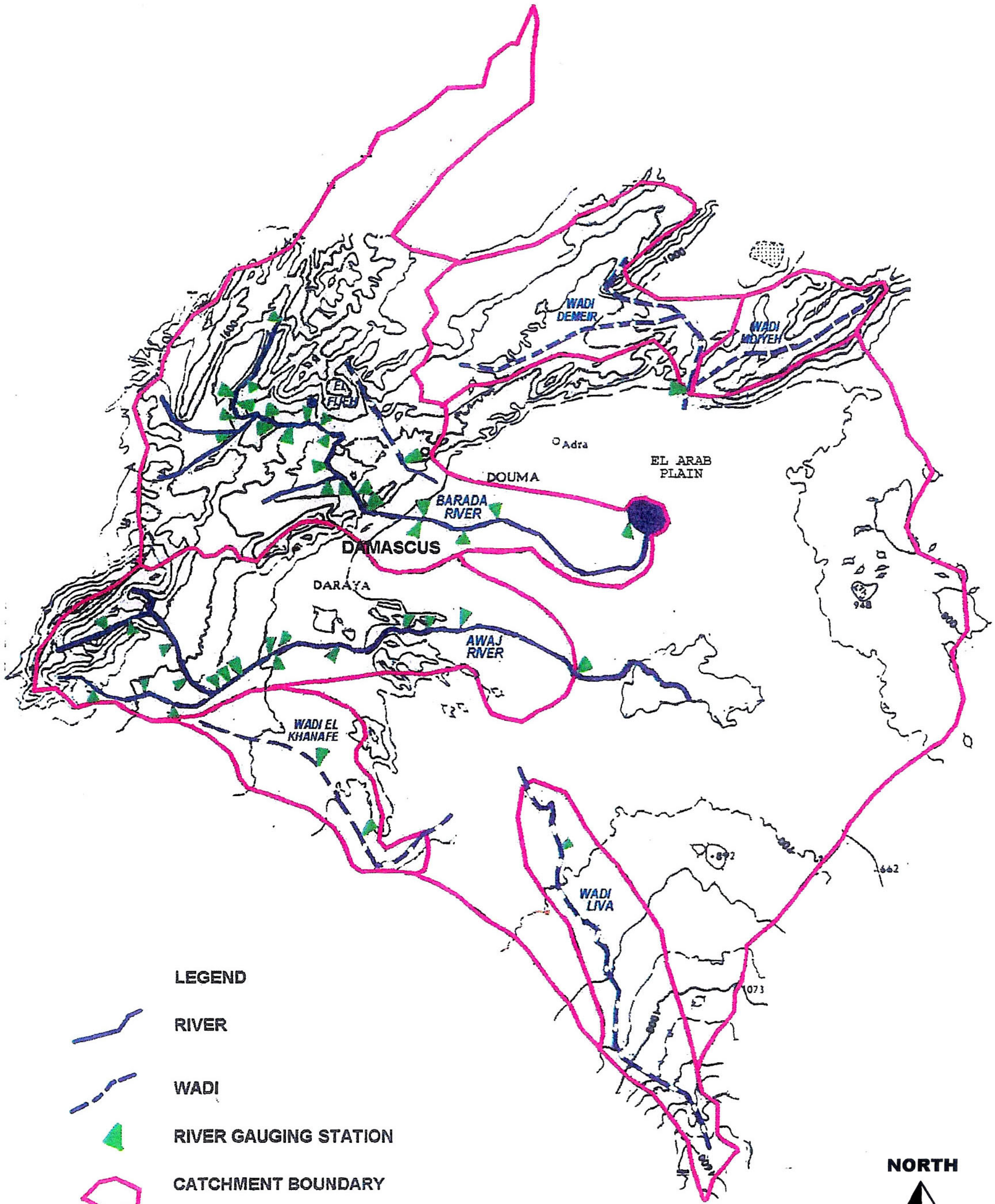

Figure 5: The Damascus River Basin (SMBH, 2008).

Barada River

The Barada River is with about 80 km the largest and most important river for the Damascus water supply as it hosts both the Barada and Ain Figeh spring water. Although today Ain Figeh spring is not contributing to the river flow during the summer

months, as it is used completely for drinking water supply in Damascus. The average annual discharge of Ain Figeh is 231 MCM (JICA, 1999).

The Barada River originates in the Anti-Lebanon at the foot of Mt Alsheer Mansour, close to the border to Lebanon about 1400 m.a.s.l. It flows along the southwest part of the Zabadani Valley and turns into a southwest direction passing through Damascus City ending in Lake Ateibeh. The annual discharge is about 305 MCM of which one half is taken for local irrigation purposes and the other half for Damascus drinking water supply. In 1983 the remaining discharge of 3 to 6 MCM was still reaching the Ateibeh Lake with its water level directly dependent on the river flow (SMBH, 2008). The natural flow regime is largely altered through the growing demand. In the summer months the flow constitutes mostly of wastewater from the Ain Figeh village. Consequently, the lake has dried up in recent years, with water reaching it only on some occasions during the rainy season (SMBH, 2008). The available data on monthly discharge has been recorded since 1931 and daily since 1981 (JICA, 1999).

Awaj River

It originates at the foothills of Mt Haramon southwest of Damascus out of two upstream tributaries, Alsebrani and Aljinani. The combined catchment is about 254 km^2 and is shared equally among both. As of a USSR Study in 1983 the average discharge of the Aljinani River is 26 MCM and is totally used for irrigation and water supply. Moving downstream new springs contribute to an average discharge of 66 MCM, which is partly diverted but at the same time replenished. Alsebrani River is collecting snow melts forming small seasonal springs, which then combine with other springs to an average annual discharge of 19 MCM.

After the confluence of the two tributaries at On Sharatiet, where gauging station was installed in 1933, the Awaj reaches an annual discharge ranging from 122 to 148 MCM, about half the discharge volume of the Barada. The available data on monthly discharge has been recorded since 1950 and daily since 1981 (JICA, 1999).

The Wadis

The Wadis Deneir, Liva, El Khanafes, and Mdiyeh only flow during the rainy months. They disappear at the edge of the alluvial plain when the flow is completely absorbed by the ground. Nevertheless they are used for irrigation of small farms and thereby somewhat reducing the contribution to the natural groundwater recharge.

Springs

In the early 1980s more than 200 springs, with a minimum discharge of 864 m^3 per day were monitored by the MOI. Most of the springs are located in the mountain region and are tributaries to the Barada and Awaj Rivers. For small springs a relationship between precipitation and annual spring flow exists, with decreases of more than 25% in a dry year (SMBH, 2008). Today most of the small springs have dried up because of the change in land use and groundwater abstraction in the spring catchment areas. In the JICA and USSR study 50 springs are mentioned with more than 10 L per second. In rural Damascus springs are contributing just 3% of the total water production (JICA, 2007).

4.2 Water Balance

To this day there are three comprehensive studies available that deal with the water balance of the Ghouta basin in detail. The first study was conducted by the former Union of Soviet Socialist Republics (USSR) in 1986, the second one by the Japan International Cooperation Agency (JICA) in 2000 and the third as a review by the

Malaysian SMBH Sdn Bhd Consulting Engineers (SMBH) in 2008. Besides those studies, an often-referenced study is from the World Bank (2001) and the yearly water balance calculated by the Ministry of Irrigation (MOI), which is published as part of a yearly report on water resources in Arabic. The SMBH (2008) reviewed both the USSR and the JICA study and added their own independent approach to calculate the water balance in the basin. All conducted water balances show a deficit, with the exception of the wet year in 2002-2003, calculated by the MOI, which has a positive water balance of 113 MCM. The yearly deficits vary from −78 MCM to −883 MCM. With such a wide gap in deficit and the different approaches done by each study no direct comparison can be made. The deficit shows, that the current practice of water use is not sustainable, causing a groundwater storage loss that is expressed in a falling water table.

Because of the wide range of deficits, which clearly shows the complex situation of the Barada and Awaj catchment, caused through natural reasons, as e.g. the unknown inter basin water transfers or the guessed factor of water demand, with no metering system existing.

Therefore in this study no single water balance was chosen as a base for comparison with the different results of water savings, but the range of the given deficits.

For the focus on cutting demand in groundwater withdrawal, the balance of the MOI is used. Only the MOI and the World Bank (WB) study separated the natural renewable resources into surface and groundwater. Whereas in the JICA and USSR study surface runoff is not dealt with as an individual parameter. It was included in the natural recharge rate, resembling the natural renewable resources.

The following section gives a short theoretical background on the different water balance components and a summary of available data for the Damascus Basin.

4.2.1 Theoretical Background

In general a water balance describes the flow in and out of a system. Looking at the water flow in quantitative way and applying the rules of the conservation of mass, it results in following equation:

$$P = R + ET + \Delta S \qquad \text{Eq. 1}$$

with *P* as Precipitation [mm], *ET* as Evapotranspiration [mm], *R* as Runoff [mm] and ΔS as Change in Storage [mm]; all units refer to a particular area and timeframe, usually taken in years.

The following figure shows the general water cycle with results from the JICA Synthetic Storage Model (SSM) run for the natural water balance from 2005 for the Ghouta Area.

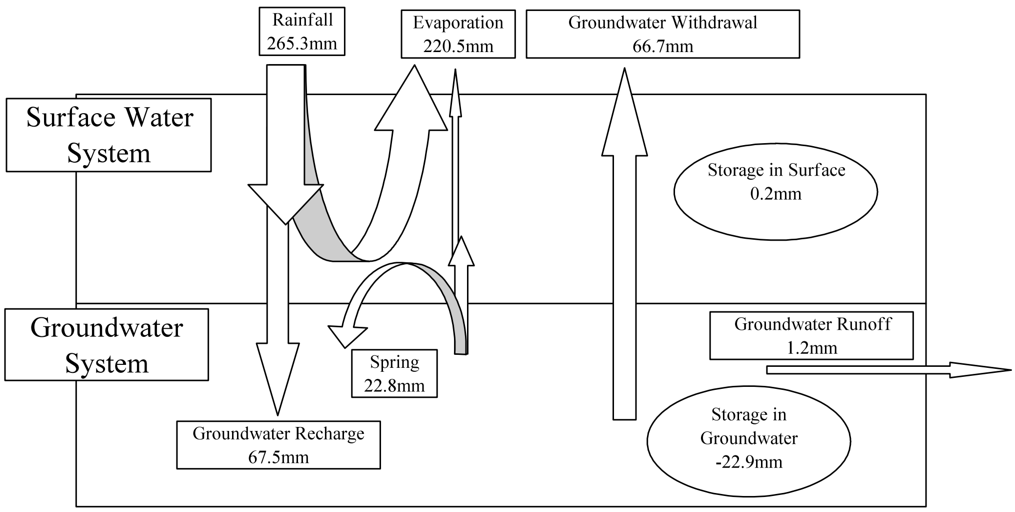

Figure 6: Natural water balance simulated with the JICA Synthetic Storage Model (SSM) by the Water Resources Information Center (WRIC) in 2005 (JICA, 2007).

4.2.2 Water Balance Components

Precipitation

In the Damascus Basin the yearly precipitation varies from a minimum of 133 mm in 1999 to a maximum of 499 mm in 2003, or 1133 MCM to 4264 MCM in volume according to MAAR statistics (2010). The total average from 1989 to 2008 is 270 mm or 2308 MCM per year. The JICA study uses an average of 2350 MCM from 1980 to 2002.

SMBH (2007) uses 2280 MCM, and WRIC (2005) 2268 MCM. The range of the precipitation values is very small going from 2268 to 2350 MCM. The basis of data is the same for all, with changes coming from different ways of interpolation of the given data. Precipitation can be as low as 933 MCM during a drought year (USSR, 1986).

Surface Runoff

As mentioned in Section 4.1.4, the Ateibeh and Hijaneh Lake are dried up and only reached by the Barada and Awaj Rivers in wet years. In normal years during the summer months all surface runoff is used for irrigation with no remaining flow in the lower reach. The annual mean runoff of both rivers is shown in Figure 7 with an annual runoff of 290 mm or 326 MCM for the Barada and 291 mm of 76 MCM for the Awaj River (USSR, 1986). The measurements for the Barada River were taken at the El Hameh station and for the Awaj River at Om Sharatiet.

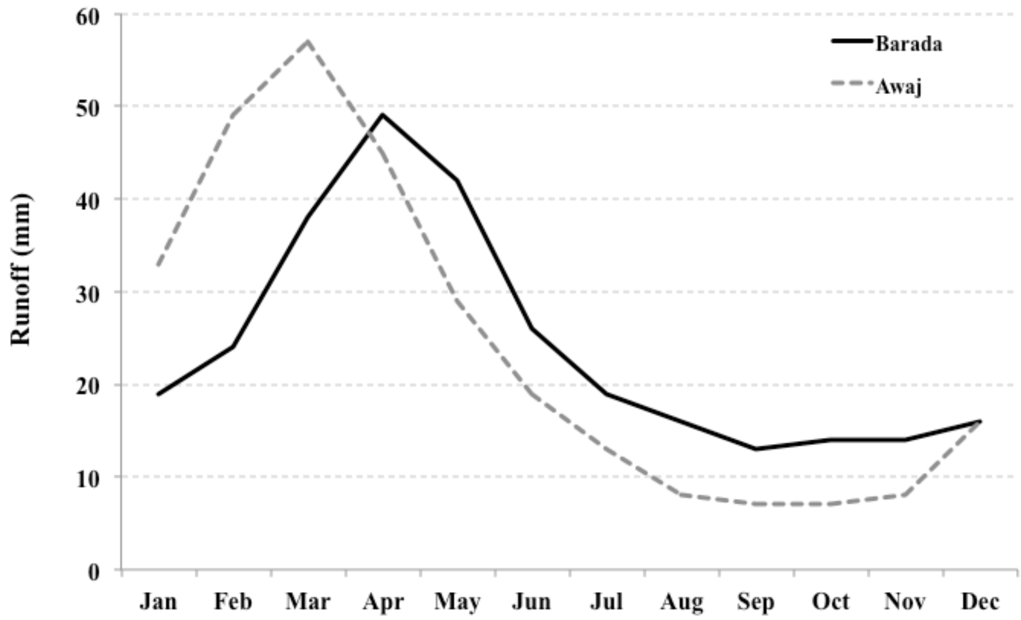

Figure 7: Annual mean runoff of the Barada and Awaj River (USSR, 1986).

Baseflow

Figures for baseflow were only directly mentioned in the JICA (1999) study and are therefore hard to compare. In the JICA study the basin has two quaternary outlets with basalt or limestone underlain along the basin border. The total groundwater outflow of those two sub-basins was given with 44.5 MCM per year.

Natural Groundwater Recharge

In the Damascus Basin, the natural renewable resources consist of the total natural recharge due to snowfall, precipitation, river seepage, vertical and horizontal flows from neighboring regions of Anti-Lebanon and Palmyra mountain ranges that flow towards the Ghouta Area. The groundwater is discharged through more than 50 springs with most of them forming tributaries of the Barada and Awaj Rivers that contribute 90% of the total surface flow.

Unconventional resources that add up to the total available resources in the basin are irrigation return flow, artificial recharge and reused domestic wastewater.

The natural groundwater recharge rates or naturally available resources for the Damascus basin according to the different reports are summarized in the following table:

Table 3: Natural available resources of the Damascus Basin.

Study	Natural recharge (MCM per year)
USSR (1986)	406
JICA (2000)	537
MOI (2001)	452
SMBH (2007)	499

Source: (SMBH, 2008); with: Union of Soviet Socialist Republics (USSR), Japan International Cooperation Agency (JICA), Ministry of Irrigation (MOI), and SMBH Consulting Engineers Malaysia (SMBH).

Comparing the different values, only the USSR study is falling out of the picture with a very low rate. The average rate of all studies is 474 MCM per year but without the USSR study it is 496 MCM. The reasons for the range of values are different approaches taken by each study.

Unconventional resources are not specifically mentioned in the JICA and USSR studies. The only available figures for this study are listed in Table 4. The figures for treated wastewater by the MOI contradict the figures given in the Malaysian Report, and do not follow suit with the capacity of the Adraa WTP itself, which is designed for a maximum of 167 MCM per year. For irrigation return flow, the Malaysian Report (2007) is using 10% of the irrigation demand as an estimate. The figures of the WB report seem plausible for that time, with the irrigation return flow representing 12% of the irrigation demand, and the then newly built Adraa WTP. It has to be noted that irrigation return flow includes partly of treated wastewater

Table 4: Non-conventional water resources in the Damascus Basin.

Study	Type	Non-Conventional Resources (MCM per year)
MOI (2002-2008)	Treated wastewater	180
	Irrigation return flow	115
SMBH (2007)	Treated wastewater	128
	Irrigation return flow	125
WB (2001)	Treated wastewater	75
	Irrigation return flow	75

With: Ministry of Irrigation (MOI), SMBH Consulting Engineers Malaysia (SMBH), and World Bank (WB).

Water Losses

In the irrigation sector water losses comprise of irrigation return flow through seepage, but not all losses reach the groundwater. Other losses that effect the return flow are (a) evaporation from river and canal water surfaces, (b) evaporation from wetted areas along the canal, (c) evapotranspiration from poplar and other trees that often line the canal, and (g) evapotranspiration from aquatic and other weeds along the canal banks. Water losses in the domestic sector through leakage are called unaccounted for water.

Water Storage

As mentioned in the section before, the water storage term defines if the overall water balance is positive or negative. In other words, if the change in storage is negative, more water is withdrawn than is available and the groundwater table decreases. The water storage is the sum of all in- and outflows of the system and is zero in a natural water balance without any demand.

4.2.3 Water Balance

In the following table the complete water balances from different studies are listed:

Table 5: Comparison of water balance calculations from different sources in Million Cubic Meters (MCM).

	FAO (2003)	WB (2001)	MOI (2003)	SMBH (2008)	USSR (1986)
Available Resources					
Total renewable	452	n/a	765	499	401
Reused treated wastewater	257	n/a	260	125	n/a
Reused agricultural drainage water	568	n/a	89	128	n/a
Total available resources	1277	900	1114	752	n/a
Water Demand					
Irrigation	1207	920	983	1279	n/a
Domestic	298	390	270	335	n/a
Industry	77	40	76	21	n/a
Evaporative loss	5	n/a	6	n/a	n/a
Total demand	1587	1350	1335	1635	479
Water Balance	-310	-450	-221	-883	-78

With: Food and Agricultural Organization (FAO), World Bank (WB), Ministry of Irrigation (MOI), SMBH Consulting Engineers Malaysia (SMBH), and Union of Soviet Socialist Republics (USSR).

The most recent simulation with the JICA Synthetic Storage Model (SSM) done by WRIC in 2005 estimated a deficit of 196 MCM (Table 6). JICA uses 772 MCM as total renewable resources, which is about 300 MCM higher compared to the other studies.

Table 6: Natural water balance simulated with the JICA Synthetic Storage Model by the Water Resources Information Center (WRIC) in 2005.

Parameter	Value (mm/ha)	Volume (MCM)
Precipitation	265.3	2268
Evaporation	-220.5	-1885
Spring Flow	22.8	195
GW Recharge	67.5	577
GW Withdrawal	-66.7	-570
GW Runoff	-1.2	-10
Storage in Surface	0.2	2
Storage in GW	-22.9	-196

Source: (JICA, 2007); with Groundwater (GW) and Million Cubic Meters (MCM).

4.3 Agricultural Sector

4.3.1 Irrigation Network

In the study area are three irrigation schemes originating from the Barada (136 km) and Awaj (138 km) perennial rivers and the Adraa Wastewater treatment plant (57 km). All schemes consist of lined canals with a width varying from 1 to 5.5 m and a depth from 0.5 to 2.5 m.

Barada Irrigation Scheme

The Barada River, running from the Anti-Lebanon Mountains through the city and after 82 km ending in the Ateibeh Lake (see section 4.1.4), is the main source of surface water for irrigation in the Ghouta.

The river can be divided into three reaches, the upper, middle and lower reach. In the upper reach, up to the village of Tkieh about 7.8 km from the source, farmers withdraw a mean annual abstraction of 2.2 MCM to grow fruit and vegetables (USSR, 1986).

The middle reach for about 30 km up to Rabouyeh Ravine has well defined contour channels within the steep slopes on either side. Irrigation supplies are either pumped or

gravity fed by the contour channels. Farmers mostly grow fruit trees on an area of about 580 ha. Within this reach the Ain Figeh spring is diverted to supply the city of Damascus. Unfortunately, from this reach on the river is polluted with domestic wastewater of the Ain Figeh village.

The lower reach of the river flows in the rainy season for about 45 km through the plain until it ends in the Lake Ateibeh. In this part the bulk of irrigation abstraction, mainly for the Ghouta and Merj area, takes place.

In total there are 22 canals going off the Barada River. These can be grouped into three categories: (I) perennial with some groundwater use, (II) perennial with conjunctive groundwater use and (III) seasonal canals, depending on the river flow and available groundwater. The river flow is shown in Section 4.1.4, with a possible seasonal abstraction only for three to six months in the winter from January to July. The name, length, width and irrigated area of each canal is taken from the USSR study (1986). On average the canal density is 123 m of distributaries and 223 m of irrigation canal per ha of irrigated land.

Awaj Irrigation Scheme

The Awaj River is the main source of surface water irrigation for the Mantikas of Qatana and Daraya in the south and southwest of Damascus. There are five main irrigation schemes supplying about 14 000 ha of irrigated land. These are: (I) The Jenani River, (II) The Sebrani River, (III) The Deirani River and Spring, (IV) The Kanakry Canal, and (V) the Awaj River. They differ in the possible abstraction periods per year with only part of the Jenani River scheme offering perennial abstraction. All others are seasonal operating in between four to eight months per year depending on the total flow

of the river at a given location. The irrigation distribution and allocation of water rights system is the same as in the Barada Irrigation scheme (see Chapter 3.2).

Adraa treated wastewater irrigation scheme

The Adraa wastewater treatment plant (WWT) was built in 1998/99 about 20 km northeast of Damascus for the purpose of treating all municipal wastewater from the City of Damascus and its Suburban areas. The treatment volume of the Adraa WWT compared to the total collected wastewater in Damascus ranges from 30-50%, with no reliable figures available (Gerlach, 2010). This equals the current volume of 100 MCM stated in the SMBH Report. These figures are more conservative than the results published by the SPC.

The wastewater irrigation scheme is supplying 18 000 ha. It consists of one reinforced concrete, open rectangular shaped main canal (MC) and four similar reinforced concrete distributaries (PC1, PC2, PC3 and PC4). The potential treatment volume of the WWT is 167 MCM per year; in 2006 the treated volume was about 100 MCM. It is expected to reach 125 MCM in 2015. The outflow is regulated in the booster pumping station to accommodate the diurnal variations of inflow. The current volume of treated wastewater is enough to supply about 7000 ha out of the 18 000 ha irrigation scheme with an irrigation efficiency of 57%. The remaining area is irrigated with groundwater. The treated wastewater quality is not suitable for unrestricted irrigation according to the WHO standards. It is not suitable for vegetables that may be eaten raw. Moreover, this water is infiltrating into the low-lying groundwater table in this area causing further deterioration of the aquifer (SMBH, 2008).

Maintenance of the Schemes

The Directorate of Water Resources (DWR) in the Governorates of Damascus City and Rural Damascus is maintaining all irrigation systems in the study area. The irrigation schedules are decided upon the DWR in consultation with the Directorate of Agriculture, the party branch, the local municipality and the Damascus Villagers' Union. Field visits indicated damaged off-take structures and gates of the irrigation canals leading to leakage into the fields. Observed were also canal fillings with rocks and waste. The establishment of water user associations (WUA) could alleviate those problems.

4.3.2 Irrigation Techniques

The dominant irrigation technique in the basin is surface irrigation covering 80% of the area, with sprinkler and drip irrigation being applied on the remaining area. The surface irrigation methods include flooding, border and furrow irrigation, with furrow irrigation as the most widely used for vegetables and basin irrigation for wheat and barley (FAO, 2003). Drip irrigation is used for vegetables and fruit trees, whereas sprinkler irrigation is used for crops.

The conveyance channels of surface water in the Study Area are mostly earthen channels with minimal regulators or control structures (SMBH, 2008). The efficiencies of these channels tend to be low in the region of 40-50%. The intakes of the on-farm channels are often made of concrete, but the further distribution nevertheless is made of earth. The overall irrigation efficiency is generally low with 40-50%, which can be explained through over irrigation (Salman, 2003). For comparison, the overall average of irrigation efficiencies in developing countries is 38% (UNESCO, 2003).

Irrigation Efficiencies

At present the estimated irrigation efficiency, used for calculating the Crop Requirements, by the MAAR is 57%. This value is a weighted average of surface water irrigation efficiency of 50% and 60% for groundwater irrigation (SMBH, 2008). This is low, especially for a water scarce area. In the JICA study a project efficiency of 50% was assumed, and in the USSR Study only the seepage loss of the irrigation network is given as 59%. In this study, the efficiency of 57% used by the MAAR was used to calculate the traditional irrigation demand and water savings in the scenarios.

Irrigation efficiencies for modern techniques depend strongly on the right use, especially drip irrigation. For drip irrigation the efficiency can be as high as 90% and for sprinkler irrigation 78% respectively (Kaisi, 2007). These figures are the results of efficiency studies for modern techniques on experimental farms in Syria from 1991 to 2000. This results in a water demand of about 10 000 m^3 per hectare, which is already used by the MOI for the water balance calculation. For this study a more conservative efficiency rate with 75% for sprinkler and 80% for drip irrigation is used. Those are based on the SMBH Report (2008).

Modern Irrigation Applicability with Wastewater

The reuse of treated wastewater for irrigation is defined in Decree 74 in 2004. In general the water quality of the irrigation water depends on the intended use. Unrestricted irrigation wastewater must comply to the same standards as any water used for irrigation. The restricted use of wastewater is grouped into three classes going from cooked vegetables to industrial crops. The general conditions in Syria comprise among others that treated wastewater may never be used in irrigating crops that are eaten raw, may never be diluted with pure water to meet the standards stipulated in this guideline

and, may never be used to recharge groundwater aquifers designated for drinking purposes. In the Ghouta Area the present water quality of the treated wastewater is not suitable for unrestricted use, but is used according to Decree 74.

In technical terms regarding the use with modern irrigation methods the chemical and physical parameters are the same as with any other water. Though, due to a higher degree of suspended solids, higher nutrient loads, salinity and pathogens different measures have to be taken accordingly. Those measures include the use of filters, adaption of fertilization, or the use of appropriate crops.

4.3.3 Illegal Well Problematic

Although the area irrigated by groundwater has remained more or less constant over the recent years, the number of wells has increased drastically (see Figure 8). Currently the number of wells in the study area is about 58 000 up in 2010 from 23 728 in 1988, out of which only 12 030 (21%) are licensed and 46 229 (79%) are unlicensed (MAAR statistics, 2008). The high number of wells can be explained through the ease and low cost of groundwater abstraction. A private well gives the farmer independency and security not relying on a possible rotation water supply through irrigation channels. An explanation by JICA is, that farmers have faced a decrease of groundwater withdrawal from existing wells and dug additional wells to irrigate their farms without licensing them.

Another explanation is the relatively low initial cost of pumps and tube well equipment and drilling, and the subsidized diesel costs. Though the cut subsidy on diesel in 2008 resulting in a price increase of 235%. Though three decisions aim at compensating the farmers for the increased costs of production (Decisions No. 27, 31, and 80 issued by the MAAR in 2008) (NAPC, 2009a). The subsidies originally intended to support the

Syrian people who mostly use diesel in winter for heating and to stimulate the economic environment through providing a cheap source of energy. They were cut as the costs started to place a great pressure on the national budget and great amounts of diesel was smuggled into the neighboring countries (NAPC, 2009b).

According to a newspaper article (Lennert, 2009) this placed additional pressure on the farmers above the prolonged and extensive drought from 2006 until today. Farmers felt the effect of the price increase for irrigation and transportation instantaneously, in some cases not being able to transport their produce to the next market, but use it as fodder for their livestock.

The recent rise of licensed wells starting in 2002 may be attributed to the government program of modernizing the irrigation techniques that started in 2000, where only farmers with licensed wells could apply.

In the year 2000 a ban on drilling new wells was imposed, if they are not used for drinking purposes. This was part of the government program to adopt modern irrigation techniques to all irrigated area (Bazza & Najib, 2003).

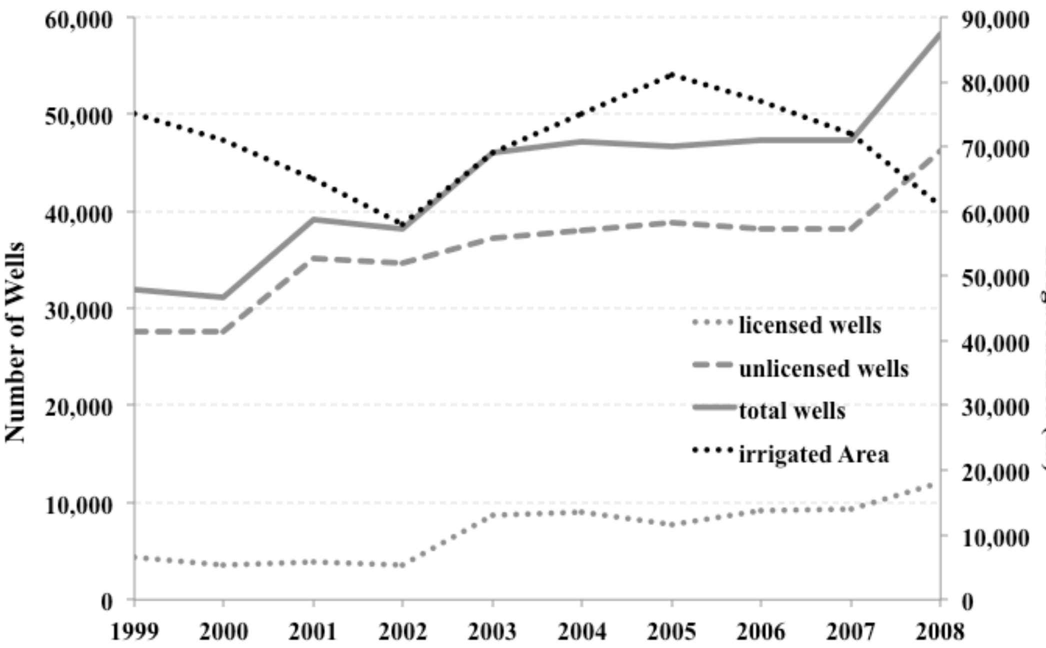

Figure 8: Number of wells and irrigated area in the Damascus Governorate.

The enforcement of laws governing the installation of new wells appears to be negligible. The high number of unlicensed wells makes it impossible to directly measure the water use and thereby prohibiting any sustainable utilization of groundwater.

4.3.4 Cropping Pattern

The type of crop that can be grown depends on the available, the soil water and the temperature regime. Regarding these parameters, the study area offers ideal conditions that allow for intensive farming for a large variety of crops with up to four harvests a year. Over the whole basin, the types of crops can be categorized as (I) summer field crops, (II) summer vegetables, (III) winter field crops, (IV) winter vegetables and (V) perennial fruit-bearing trees.

The most common grain crops are wheat, barley and corn. Grain legumes are mostly made up of lentils, chickpeas, dry beans, peas, and vetch. Fodder crops are mostly pasture crops such as barley, vetch, alfalfa and corn. A great variety of vegetables is

grown both in winter and summer including tomatoes, peppers, eggplants, okra and squash. Fruit trees that are grown include olives, grapes, figs, apricots, nuts, pears, plums, cherry and peach (JICA, 1999). The main crops in the Damascus basin in order of the cultivated area for 2009 are listed in the following table:

Table 7: List of main crops in the Damascus Basin by area.

Crop	Area (ha)	Area of Total (%)
Wheat	10813	16
Almond Tree	13163	19
Olive Tree	12740	19
Apple Tree	10128	15
Vegetables	6055	9
Barley	1259	2
Potato	1116	2
Vetch	1050	2
Total	56324	83

Source: (GCSAR, 2009).

For the estimation of water use requirements, it is important to know that the MAAR uses the term “land under crops” for agroforestry, the combination of short-term crops with perennial trees in their statistics (SMBH, 2008).

4.4 Domestic Sector

4.4.1 Demographics and Water Consumption

Demographics

The most recent census was carried out in 2004. Since 1970 the growth rate for Damascus City is on a declining trend as wells as for Rural Damascus since 1981 (see Table 8).

Table 8: Summary of 2004 census data for Damascus Metropolitan Area (DMA).

	Year				Growth Rates (%)		
	1970	1981	1994	2004	1970-1981	1981-1994	1994-2004
Damascus City	836 668	1 111 657	1 393 374	1 551 846	2.62	1.75	1.08
Rural Damascus	621 266	912 824	1 641 698	2 273 073	3.56	4.62	3.31
DMA	1 459 904	2 026 462	3 037 066	3 826 923	3.03	3.16	2.34

Source: (SMBH, 2008).

Future population growth was estimated by RECS (2007) with a population forecast as is shown in Table 9. The calculations for the future demand scenario will be based on those numbers.

Table 9:Planned future population for the Damascus Metropolitan Area (DMA).

	Planned population			
	2010	2015	2020	2025
Damascus City	1 625 800	1 691 800	1 749 100	1 800 000
Rural Damascus	2 610 500	3 091 700	3 623 200	4 200 000
DMA	4 236 300	4 783 500	5 372 300	6 000 000

Source: (RECS, 2007).

Water Consumption

The per capita domestic consumption is based on the study of billing records and the readings of customers' meters. Estimations on water consumption have been made by

SMBH and RECS, as well as by DAWSSA itself. The gross domestic demand, or metered consumption in the year 2000, including the non domestic and UFW portion, varied from 140 to 270 liter per capita per day (LCD). The differences indicate varying assumptions on the non domestic and UFW portion. For this study the proposed per capita consumption was based on the combined average figures of the SMBH Study (2008), see Table 10. The demand is increasing, as the consumption level of Rural Damascus is predicted to reach the same as Damascus City in the future.

Table 10: Proposed domestic consumption in liter per capita per day (LCD).

	2010	2015	2020	2025
Per capita domestic consumption (LCD)	100	105	105	105

Source: (RECS, 2007).

The resulting domestic demand based on the consumption and population is summarized in Table 11.

Table 11: Prediction for the total domestic water demand in Million Cubic Meters (MCM) per year.

	2010	2015	2020	2025
Damascus City	59	65	67	69
Rural Damascus	95	118	139	161
Total	155	183	206	230

Non Domestic Demand

The non domestic component includes commercial, institutional and industrial water demand. According to the JICA Study (1999) the combined commercial, religious and institutional demand was 30%. The industrial demand is about 5% of the total potable water demand (SMBH, 2008). For the scenarios the percentage of 35% for non domestic demand was used.

Unaccounted for Water (UFW)

UFW is the difference of the input volume of water and the actual volume of billed water. Unbilled water such as public water for mosques, parks, etc. is categorized as UFW. Technical losses of the supply network, meter malfunction and informal uses are added to the unbilled water. In 1997 UFW of Damascus City was 62.7% and since then was reduced to 23% at present (SMBH, 2008). In Rural Damascus the UFW is 50% due to higher informal abstraction and the bad condition of the supply network as the main reasons. For the domestic water demand scenario in the year 2025, the UFW for is estimated to decrease, due to network modernization to 20% in Damascus City and to 30% in Rural Damascus.

4.4.2 Water Production

The water production will be presented separately for Damascus City and Rural Damascus, in respect to the history of the just recently merged establishments.

Damascus City

For the Damascus City supply area, spring water and/or pumped well water is used after chlorination without treatment. The production volume is not controlled on demand but depends on precipitation and fluctuates over the year. The main source with 87% is the Ain Figeh and Barada spring with well fields only operating when the combined spring flow is not sufficient to cover the demand.

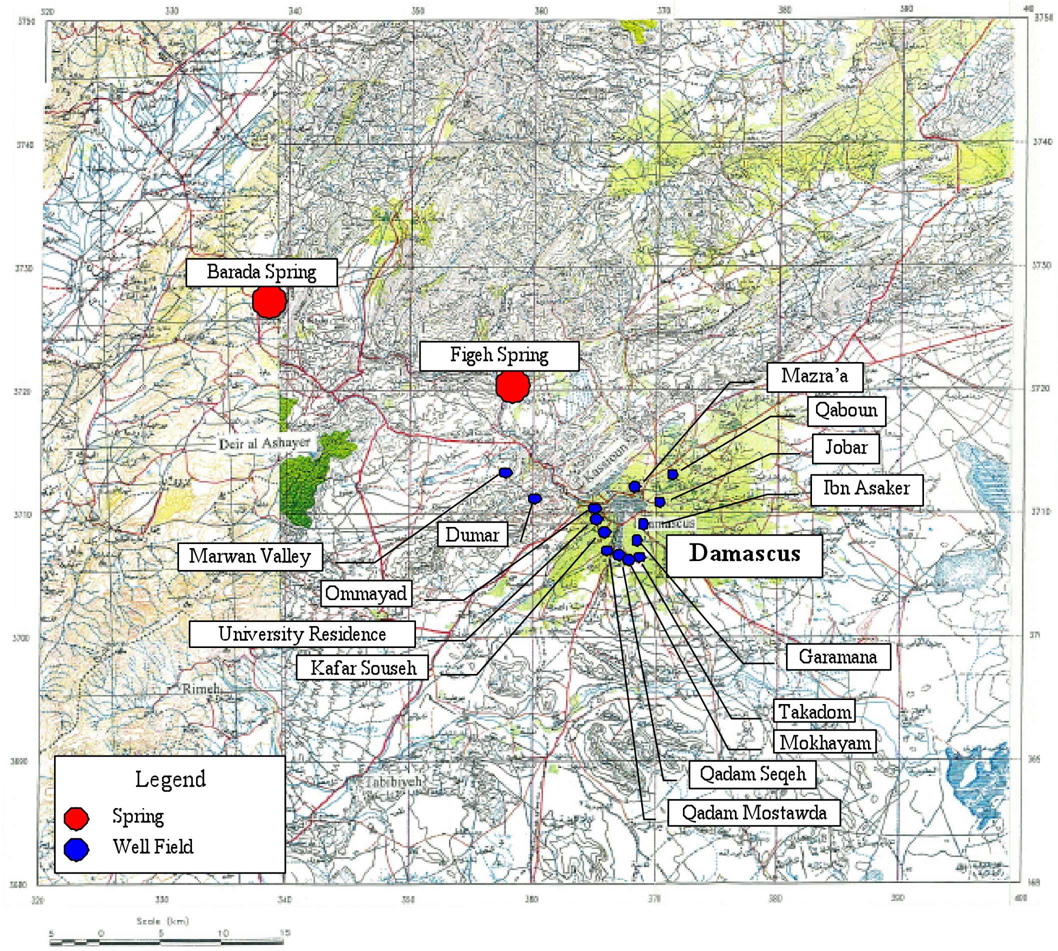

Figure 9: Damascus City drinking water resources showing springs and well fields (RECS, 2007).

Ain Figeh and Barada Springs

Ain Figeh Spring is about 16 km from Damascus City. About 60% of rainfall recharges the catchment with an average natural spring flow of 231 MCM per year. The discharge varies from 233 280 m^3 d^{-1} in dry years to 1 114 560 m^3 d^{-1} in wet years, averaging in 665 280 m^3 d^{-1}. Water abstraction from the main and side springs is done by four well fields with 27 production wells. Their total pumping capacity is 730 000 m^3 d^{-1} to cover the demand in the wet season. The average yearly abstraction from 1986 to 2001 was 150 MCM, or about 65% of the natural discharge. In dry years it can reach 90% due to small discharge (SMBH, 2008).

The Barada springs have a pumping capacity of 36.5 MCM and are operated when Ain Figeh springs are not able to meet demand. The pumped water is conveyed to about 15 km to the Ain Figeh collection, where it is combined with Figeh Spring water (see Section 4.1.4).

The drinking water is supplied by gravity flow through two tunnels and stored in four reservoirs from where it is distributed to other service reservoirs. The old tunnel has a flow capacity of 302 400 m^3 d^{-1}, compared to the new tunnel with an estimated flow capacity of 976 320 m^3 d^{-1} (RECS, 2007). The combined conveyance capacity is 1 175 000 m^3 d^{-1}, equaling more than double of the present water production.

Wellfields

There are a total of 14 well fields in and around the city (see Figure 9) with a total capacity of 41 MCM per year and emergency wells that act as standby wells of an extra 20 MCM. They are operated in when spring water is short of demand. The operation of wells is regulated through the groundwater level rather than pumping capacity. The average annual abstraction in the time period from 1986 to 2002 was about 25 MCM (SMBH, 2008).

In Damascus city the total average production value during the years from 1996 to 2009 was 192 MCM, with a maximum of 223 MCM in the high water season and a minimum of 161 MCM representing the short-water season. The total water production is shown in Figure 10.

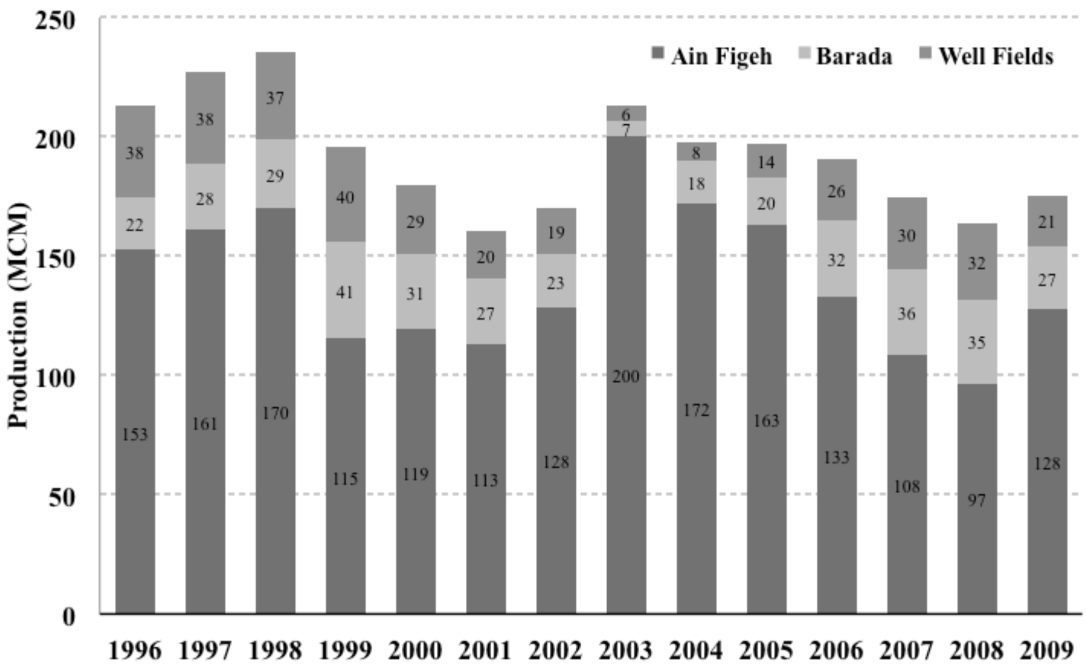

Figure 10: Damascus City water production values from 1996 to 2009 in Million Cubic Meters (MCM) (DAWSSA, 2010).

Rural Damascus

In Rural Damascus the trend of water production is going up, due to the rapid population growth, irrespective of water resources conditions. In 1996 the production was 60 MCM and in 2009 already 139 MCM, an average increase of 9.5% per year. The water supply consists principally of groundwater with 1 223 production wells and a capacity of 200 MCM and 21 springs with a capacity of 84 MCM. Spring water accounts for about 3% of the total production (RECS, 2007). The production rate is estimated by operation time multiplied with the flow rate for each well. The flow rate depends on the groundwater table and is usually measured once a year. This figure has to be used with caution, as the operation time of the wells is not 24h, but more around 12h.

Exemplary for the year 2009 the volume of the overall water production with the unit production in liter per capita per day (LCD) is shown in Table 12. The unit production is a theoretical value from which UFW has to be subtracted.

Table 12: Water production volume in the year 2009 with the unit production in LCD (liter per capita per day).

	Unit	Damascus City	Rural Damascus	Total
Water Production	MCM	176	139	315
Served Population	1000 persons	1 625	2 610	4 235
Unit Production	LCD	297	146	204

Source: DAWSSA (2010); with: Million Cubic Meters (MCM), Liter per capita per day (LCD).

5 Methodology

This work is based on (i) review of studies carried out by governmental authorities and external institutions, (ii) data analysis and interviews with officials for data verification, and (iii) development of water demand scenarios for the agricultural and domestic sector to see the effect of water savings on the overall water balance.

Literature Review and Evaluation

The literature review included reports from ministries, institutions, consulting companies and scientific papers. It concentrated on the institutional, administrative, and legal framework including governmental policies. WDM options on the current water use of the agricultural and domestic sector as the biggest users were examined. Options were directed at the main question of this study on possible water savings and their effects on the water balance.

The evaluation compared the collected information to get an idea about its credibility and to see the range of the given data at the same time.

Assessment and Analysis of Relevant Data

Hydrologic data for the natural water balance from different studies and the impact of climate change on the water balance was assessed. Further data on present water demand in the agricultural and domestic sector were assessed and analyzed. These data included the crop specific cultivated area, crop water requirements, and irrigation technique efficiencies for estimating to agricultural demand. Data for estimation of the domestic demand were demographic, water production and consumption rates, unaccounted for water and non domestic demand.

The effect of WDM options on the water balance was assessed. The options that were dealt with in this study were (a) the modernization of the network itself to reduce the physical losses and (b) the potential of saving water by raising the tariff to reduce the per capita use. The relevant data, as demographic data, per capita water use and the water network efficiency will be collected. The effect of the modernization of the water network will be analyzed for the Greater Damascus network, as the city network has been upgraded recently.

5.1 Management Scenarios in the Agricultural Sector

Four different WDM scenarios have been developed to illustrate possible water savings in the agricultural sector:

I. Impact of Modernization of the Conveyance System
II. Impact of Modern Irrigation Methods
III. Impact of Change in Cropping Pattern
IV. Impact of Treated Wastewater Reuse for Irrigation

Impact of Modernization of the Conveyance System

The first scenario was developed to see the potential of possible water savings through the modernization of the conveyance network. The impact of the conveyance system on the water balance is difficult to estimate due to different reasons, such as missing data on secondary and tertiary canals, or the variations of temporal usage of schemes depending on precipitation. Therefore only ideas about the impact of savings can be given in this scenario.

Two options have been assessed: (i) loss through evaporation and (ii) loss through seepage. To calculate water being lost through evaporation, the total area of the canals

was roughly estimated and combined with the local evaporation rate. The seepage loss was estimated with the conveyance efficiency rate.

Impact of Use of Modern Irrigation Methods

The second scenario gives an outlook about the volume of irrigation water that can be saved by converting irrigation techniques. The modernization includes the conversion of all traditional techniques into modern techniques. The outcome demonstrates the possible reduction of the agricultural sector water demand, and its effect on the deficit of the overall water balance. The scenario represents the current government project of NPCMI (see section 2.1.3) aiming to convert all irrigation techniques to modern techniques on a national scale. To calculate the total irrigation water demand the following equation was used:

$$water\ demand = \frac{crop\ area \times crop\ water\ requirements}{application\ efficiency}$$

Water demand calculations were based on application efficiencies not considering conveyance efficiencies outside the farm. This way of estimating the water demand is the most common, when no data on the actual amount of water used for irrigation is available.

The crop water requirements are published yearly by GCSAR, the agricultural research branch of the MAAR and were available for the year 2008-2009. They depend on climatic factors and growth stage of the plant and thereby differ each year. The data is grouped into seasonal and perennial crops and according to the water source, in this case ground-, surface-, and treated wastewater. For this study the data was prepared further and grouped according to the applied irrigation technique.

The average monthly net CWR values for the year 2009 are shown in Figure 11 under the assumption that all crops are equally distributed over the whole area. The CWR values for each crop is listed in Appendix A and B.

The following assumptions on the use of different irrigation technique were made. All fruit trees and vegetables are irrigated with drip and all other remaining crops with sprinkler irrigation. An overview on the crop groups according to the water source of either groundwater (GW) or surface water (SW) is shown in Figure 12.

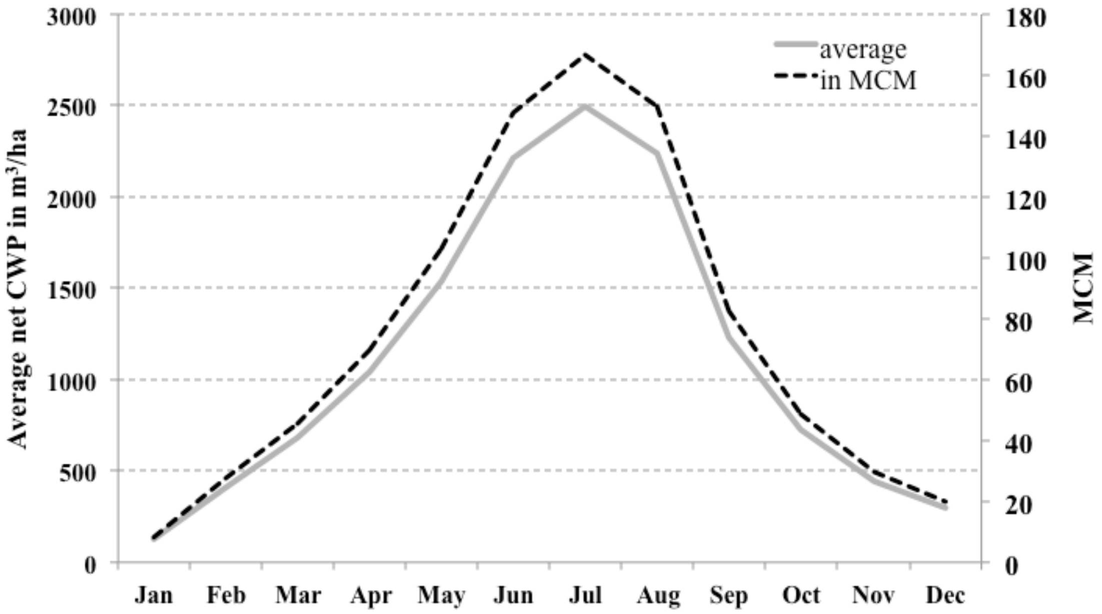

Figure 11: Average net crop water requirements for the whole Ghouta Area in m³/ha and in million cubic meters (MCM).

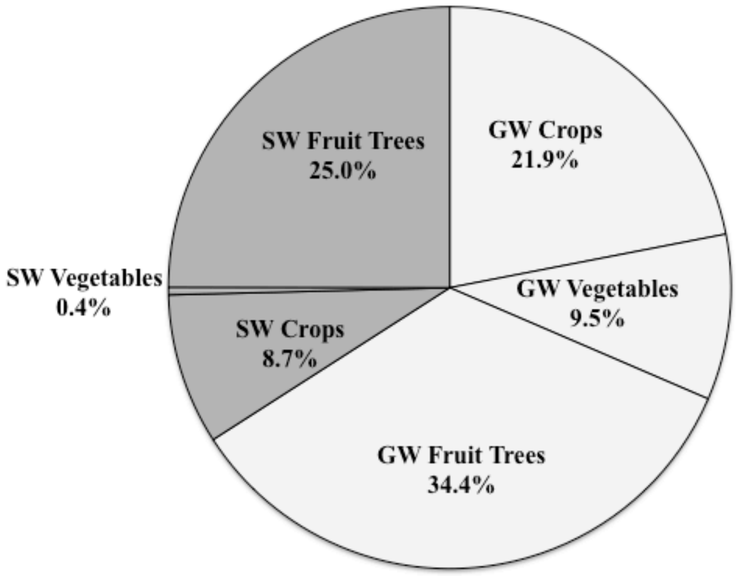

Figure 12: Crop groups and their respective area the Ghouta according to the water source: groundwater (GW) or surface water (SW).

In Table 13 data is listed as it was used in the scenarios. It is grouped according to the water source, irrigation method, crop group, corresponding area and net crop water requirement.

Table 13: Overview about the used crop groups according to the irrigation method and water source for 2009.

Water Source	Irrigation Technique	Crop Group	Area (ha)	Net Crop Requirement (MCM)
Groundwater	Sprinkler	Crops	15834	84
	Drip	Vegetables	6882	37
		Trees	24846	324
Surface Water	Sprinkler	Crops	904	4
	Drip	Vegetables	314	2
		Trees	18023	234
Wastewater	Sprinkler	Crops	5363	16
		Total GW	47562	446
		Total SW	19241	240
		Total	72166	701

With: Million Cubic Meters (MCM).

Table 13 builds the basis for the efficiency calculations. The net crop requirement was used to apply different irrigation efficiencies and to calculate the corresponding demand. With this set up, the direct effects of water savings for each water source are easy to distinguish.

Two assumptions for the conversion to modern irrigation methods have been developed. Variation (A) is changing all techniques in the whole study area, according the government plan, while Variation (B) is only changing part of the study area.

For Variation (B) it was assumed that not all techniques will be replaced, as the change can be questionable for certain reasons. The Japan International Cooperation Agency (JICA) in their project on Efficient Irrigation Techniques and Extension in Syria (DEITEX) pointed out that it is not affordable for, e.g. supplementary irrigated crops like winter wheat to be converted to modern techniques. Another difficulty is the quality of the current wastewater. If no tertiary treatment is introduced, the unrestricted use of wastewater is not applicable and thereby the cultivation with wastewater of a greater area (see section 4.3.2). For the second scenario an area of 43 000 ha or 60% of the total Ghouta Area was found suitable by the DEITEX project. To calculate the demand only vegetables with the area of 6882 ha were converted to modern techniques and half of all tree plantations together resembling the 43 000 ha to be converted.

Impact of Change in Cropping Pattern

To get an idea on the amount that could be saved with a change in cropping pattern this scenario was developed. It is a theoretical approach, not taking into account any economic or social factors. Cropping patterns in the Ghouta Area are up to the farmer, with no authority dictates them what to cultivate as in other areas, where strategic crops are grown. Most of the area is irrigated with groundwater. With low tariffs and no incentives to save water, the farmers cultivate what makes the most money. In the following table the most water intensive crops are listed.

Table 14: List of water intensive crops in the Ghouta Area in the year 2009.

Plant	Area (ha)	Area (%)	Net crop water requirement (MCM)
Almond	13163	18	173
Olive	12740	18	151
Apple	10128	14	145
Wheat	10813	15	63
Alfalfa	2284	3	33
Forest	2001	3	28
Vegetables	5874	8	26
Grape	2128	3	24
Potato	983	1.4	11
Vetch	2500	3.5	7

With: Million Cubic Meters (MCM).

In Table 14 the most water intense crops over its grown area in the Ghouta are listed. The top four (Almond, Olive, Apple, and Wheat) cover 65% of the total area and consume 532 MCM or 76% of the total net crop requirement. The least water intensive crops are listed in Table 15 according to their after their individual crop water requirement.

Table 15: Least water intensive crops in the Ghouta Area in the year 2009.

Plant	Area (ha)	Area (%)	Total (m^3/ha)	Net crop water requirement (MCM)
Barley (fodder)	2363	3.3	1846	4.4
Peas (green)	180	0.2	1945	0.4
Barley and Vetch	1001	1.4	2036	2.0
Vetch (fodder)	227	0.3	2119	0.5
Vegetables	6055	8.4	2506	26
Garlic	474	0.7	2740	1.3
Barley (fodder)	225	0.3	2815	0.7
Peas (dry)	170	0.2	2863	0.5
Vetch	3550	4.9	2883	10.1
Anise	478	0.7	4145	2.0
Barley	1257	1.7	4250	5.3

With: Million Cubic Meters (MCM).

The following crops were exchanged, leaving the size of the cultivated area untouched: barley with fodder barley, vetch with fodder vetch, potatoes with dry peas, and alfalfa with vetch. These crops were chosen only on behalf of their high and respectively low water requirement.

Impact of Treated Wastewater Reuse for Irrigation

The fourth scenario is about increasing the share of treated wastewater and thereby area used for irrigation. The used output of the Adraa treatment plant was 167 MCM, according to the original design of the plant that will be reached in the foreseeable future. Also the forecasted available amount of 350 MCM of treated wastewater in the year 2025 by JICA was used to estimate the potentially irrigated area. This off-farm scenario shall give an outlook on the potential of treated wastewater as a non-conventional resource that can be used for irrigation or groundwater recharge. Also the effect on the water balance through a reduced groundwater demand for irrigation will be shown.

5.2 Management Scenario in the Domestic Sector

The increase of domestic water demand is going to be estimated from 2010 to 2025. The approach to estimate the total water demand was kept simple, using components from other studies, where they have been elaborated. All components were described in Section 4.4.1. The estimation is not including seasonal fluctuations in monthly water production values.

The estimations in the WDM scenario included both the reduction of UFW as means of physical losses from 50% to 30% in Rural Damascus and the growing population until the year 2025. The population forecast, the unit consumption of 105 LCD, and the share of non domestic water with 30% was taken from the JICA Study (2007). Total water demand estimations have been calculated as follows:

$$water\ demand = \frac{population \times unit\ consumption + non\ domestic\ demand}{1 - physical\ losses}$$

The sensitivity of estimating the domestic demand is shown by using different water consumption rates. Thereby the effect of both uncertainties, the actual population figure and the actual water consumption on the demand can be shown.

All scenarios from the irrigation and domestic sector will be used in an overall water balance and compared to other studies. Thereby the possible water savings in regard to the total water demand in the Damascus basin will be assessed.

6 Results and Discussion

6.1 Scenario Outcomes of the Agricultural Sector

6.1.1 Conveyance System Modernization

Evaporation Loss

The average yearly potential evaporation rate is 1906 mm determined with the Class A pan (JICA,1999). The dimensions of the main canals results in an area of 0.77 km^2 and were taken out of the SMBH (2008) report. The total evaporation loss, if those channels were used continuously, is about 1.5 MCM.

The ratio of the total canal length to the length of its distributaries is 123 m to 223 m or 1:1.8 for the study area (USSR, 1983). But even by doubling the area, evaporation loss amounts only to 3 MCM, which could be saved if the canals were transformed into a closed pipe system. Compared to the overall irrigation demand of 1230 MCM by using traditional irrigation methods, the actual gain of closing the conveyance system is questionable.

Loss through seepage

The potential for water savings through conveyance improvement is expected to be high. The seepage loss of water transport network is estimated to be 59% in the USSR study. The total surface water demand includes the conveyance efficiency e_c and field application efficiency e_a and was estimated in this study as 421 MCM. The area that is irrigated with groundwater is not analyzed, as the usual short conveyance ways from the well to the field are already considered with a higher efficiency rate.

To get an idea the following example was used with the Adraa wastewater irrigation scheme. In this scheme the supply of 100 MCM per year is known. The calculated

seepage loss is 41 MCM with an e_c of 59% or 20 MCM with an e_c of 80%. Thereby the possible savings would be 21 MCM per year. Adding the other two irrigation schemes the potential is even higher. Though these numbers have to be used with caution, as stated in the beginning of this section.

Another point not to be forgotten is that seepage loss on the other hand is decreasing the scheme irrigation efficiency, but at the same time adds to the groundwater recharge. The SMBH report is using 10% of the water used for irrigation as aquifer recharge.

A study from Al Hassa in Saudi Arabia, where an open concrete channel was replaced by a PVC pipe, showed an increase in the distribution efficiency of 25% (Aldakheel, 2007). In general by improving the conveyance efficiency, the scheme irrigation efficiency is also increased.

At this point the government has started a project in Al Yarmouk 1997 to replace open canals with pressurized submersed pipes to minimize conveyance losses and illegal abstraction by farmers (Salman, 2002). In 2001 a national project was established working on the rehabilitation and modernization of old irrigation projects to improve the conveyance efficiency and reduce physical canal losses (Farahani, 2006). Regarding the overall low conveyance efficiency in the study area, there is considerable scope to increase the overall irrigation efficiency at conveyance and field level. Without a concrete figure of water savings it was not included in the overall water balance.

6.1.2 Use of Modern Irrigation Methods

The water demands for traditional and modern irrigation efficiencies were calculated and compared as shown in Table 16.

Table 16: Comparison of irrigation demand between traditional and modern techniques.

Water Source	Irrigation Technique	Crop Group	Area (ha)	Total Net Crop Requirement (MCM)	Water Demand Traditional (MCM)	Water Demand Modern (MCM)	Water Savings (MCM)
Groundwater	Sprinkler	Crops	15834	84	148	112	36
	Drip	Vegetables	6882	37	64	46	19
		Trees	24846	324	569	405	164
Surface Water	Sprinkler	Crops	904	4	6	5	2
	Drip	Vegetables	314	2	4	3	1
		Trees	18023	234	411	293	118
Wastewater	Sprinkler	Crops	5363	16	27	21	7
		Total GW	47562	446	782	564	218
		Total SW	19241	240	421	300	121
		Bulk Total	72166	701	1230	885	345
		Water use (m^3 per ha)		9717	17048	12266	

With: Million Cubic Meters (MCM), Groundwater (GW) and Surface Water (SW).

The net crop water requirement is 701 MCM for all Ghouta. This amount is theoretical and raised through the inefficiencies in conveyance and irrigation application. By using traditional methods the overall demand is 1 230 MCM in total or 17 048 m^3 per hectare. This corresponds well with the results of the JICA Study in 1999 who estimated a demand of 1 279 MCM or 18 000 m^3 per hectare.

The use of modern irrigation methods, if all techniques are converted, as promoted by the MAAR, needs 885 MCM per year or 12 266 m^3 per hectare. That equals total savings of 345 MCM per year or 28% respectively. This amount is made up from 121 MCM of surface water and 218 MCM of groundwater. If compared to the current deficit of 311 MCM issued by MAAR, the water balance would be evened with a small surplus.

If using a universal efficiency rate of 80%, regardless of the actual used technique (drip or sprinkler), the total demand would be 877 MCM compared to 885 MCM calculated with different efficiency rates. The difference between the two approaches is 0.9%.

Variation (B) with only 60% of the Ghouta Area converted to modern techniques resulted in total savings of 219 MCM, or a total demand of 1 003 MCM. This equals 63% compared to the theoretical 345 MCM that could be saved with a change of all techniques.

A simple linear approach to calculate the demand after conversion, for a smaller area, regardless of the crops, results in savings of 207 MCM or 60% of 345 MCM. This equals 91% of the savings with regard of the crops that are suited for conversion or not.

6.1.3 Change in Cropping Pattern

The scenario was calculated with the use of modern and traditional irrigation methods. The change of cropping pattern reduced the demand to 837 MCM from 885 MCM and with the use of traditional methods to 1 163 MCM from 1 230 MCM. The savings with modern irrigation methods were 48 MCM and under traditional 67 MCM, respectively.

If only alfalfa would be replaced with e.g. vetch, the total savings would be 26 MCM. This makes alfalfa to carry a key role and it should be considered if any change in cropping pattern is planned or realized.

6.1.4 Treated Wastewater Reuse for Irrigation

With the modernization of irrigation techniques and an irrigation efficiency rate of 75% for sprinklers, the supplied 167 MCM could irrigate an area of 12 525 ha. Under such circumstances the need of groundwater to irrigate the remaining 5 475 ha is greatly reduced to 96 MCM, a reduction of 88 MCM (see Table 17).

Table 17: Impact of higher wastewater share used for irrigation on the Adraa wastewater scheme (18 000 ha) and corresponding savings in groundwater.

	Irrigation Technique	Area irrigated with WW (ha)	Area irrigated with GW (ha)	GW for Irrigation (MCM)	GW Savings (MCM)
Current 100 MCM	Traditional	5700	12300	216	
	Modern	7500	10500	184	
Designed 167 MCM	Traditional	9519	8481	149	67
	Modern	12525	5475	96	88

With: Million Cubic Meters (MCM), Wastewater (WW), Groundwater (GW).

Groundwater savings of 88 MCM would reduce the current water balance deficit, estimated by the MOI, of 311 MCM by 30%.

The reuse of treated wastewater proved to be an effective and integrated way of reducing the deficit. It ensures greater food security and thereby fulfills two objectives of the current national policy: i) safe environment and ii) improved agricultural production. The economic costs of building new treatment plants and maintenance could be regained through a change of the tariff system that is oriented on cost recovery.

Syria is already one of the largest users of treated wastewater in the Middle East, with 1 364 MCM of total produced and reused wastewater (Aquastat, 2008). Nationally it accounts for 3% of the total water used for irrigation, next to 13% of reused agricultural drainage water and 84% fresh water.

The Additional Use of Treated Wastewater in the year 2025

In the following scenario, a higher population and thereby increased volume of treated wastewater is estimated according to the "Study on Urban Planning for Sustainable Development of Damascus Metropolitan Area" (JICA, 2007). The study includes a detailed view about the water demand and supply in 2025, and its projections are used in this scenario for the estimations of groundwater savings.

The estimated human population of Greater Damascus is estimated to be 6,1 Mio in 2025 with a total domestic water demand for Greater Damascus of 474 MCM compared to a population of 4,2 Mio today and a current demand of 419 MCM. The increase in demand is not linear to population growth, as the amount of unaccounted for water is reduced through improvements of the water supply network at the same time.

The total domestic water demand of 474 MCM would be covered with 196 MCM originating from the Ain Figeh and Barada Spring and 278 MCM from groundwater withdrawal.

With new decentralized wastewater treatment plants, the planned amount of treated wastewater is 350 MCM in 2025 (JICA, 2007). With the use of modern irrigation techniques and a conservative demand of 12 266 m^3 per hectare it could be used to irrigate 28 533 ha. Using the demand estimation from the MOI of 10 000 m^3 per hectare, it would be enough to irrigate 35 000 ha of farmland. Out of 47 562 ha, the total area irrigated with groundwater, this would represent 60% or 74%.

Total Groundwater Savings

To meet the growing demand in the domestic sector, the groundwater production would increase to 304 MCM in 2025 from 249 MCM today. The groundwater savings were calculated under the assumption that the additional 250 MCM of wastewater, compared to 100 MCM today, would only replace the irrigation demand from groundwater. The total planned amount of treated wastewater is be 350 MCM, or 62% of the total demand from groundwater of 564 MCM. The increase of 55 MCM in groundwater withdrawal for the domestic sector has to be subtracted from the direct savings of 250 MCM from treated wastewater. With all made assumptions, the amount that could be saved from groundwater abstraction is 195 MCM, with the use of modern irrigation techniques and the increase of groundwater demand in the domestic sector (see Table 18).

Table 18: Projected groundwater savings in 2025 using a higher share of treated wastewater.

	Water Production (MCM)	Production from SW (MCM)	GW Domestic Demand (MCM)	GW Irrigation Demand (MCM)	Treated WW (MCM)	Savings in Irrigation Demand (MCM)	Total GW savings (MCM)
2010	325	196	249	782	100		
2025	448	196	304	564	350	250	195

With: Million Cubic Meters (MCM), Wastewater (WW), Groundwater (GW), and Surface Water (SW).

Though it has to be noted that production values are lower for a drought year effecting groundwater savings with more groundwater being pumped up to satisfy the domestic demand. Moreover JICA suggests that in a drought year the total available resources (ground and surface water) for other uses than domestic, will be 500 instead of 700 MCM.

6.1.5 Summary of Agricultural Scenarios

In order to conclude the scenarios the overall water saving potentials are summed up in the following section. The direct water savings from the Modernization of Irrigation Techniques and Changing of Cropping Pattern Scenarios are listed in Table 19.

The realization of both scenarios, changing irrigation techniques and cropping pattern resulted in combined total water saving of 388 MCM for changing all techniques (Variation A) or 268 MCM by changing only 60% of the irrigated area (Variation B). Compared to the water balance calculated by the MOI with a current deficit of 311 MCM, the water savings of Variation A would result in a little surplus of 77 MCM. Variation B with water savings of 268 MCM would reduce the deficit to 43 MCM. But compared to the Malaysian Study (SMHB, 2008) with a water balance deficit of 883 MCM the savings alone would only half the current deficit.

Table 19: Overview of calculated Groundwater (GW) and Surface Water (SW) saving potentials with the use of modern irrigation techniques and change in cropping pattern.

Scenario		GW Savings (MCM)	SW Savings (MCM)	Combined Savings (MCM)
Modern Techniques	Variation A: 100%	218	121	339
	Variation B: 60%	98	121	219
Cropping Pattern		36	13	49
Total Saving (A)		254	134	388
Total Saving (B)		134	134	268

With: Million Cubic Meters (MCM).

The treated wastewater scenario is separated, because it is not saving water directly but is dealt with as an available non-conventional water resource that could be used for irrigation. The current policy of wastewater treatment aims at decentralization. All new wastewater treatment plants have to disclose areas for irrigation and groundwater recharge with treated wastewater (CES and GFA, 2008). The groundwater savings

through the use of treated wastewater therefore only show the potential and were not taken into account for the overall water balance.

6.2 Scenario Outcome of the Domestic Sector

In Table 20 the total domestic water demand forecast for the year 2010 until 2025 is shown. Thereby the total domestic water demand increases from 365 MCM in 2010 to 411 MCM in 2025. This would mean, that the current demand is higher than the current production of 315 MCM, with a supply deficit of 50 MCM. In Rural Damascus the population already depends on buying additional water from other sources, such as water tankers or bottled water.

Table 20: Estimation of total domestic water demand from 2010 until 2025. Calculated with an per capita consumption of 105 L per day and 30% share of non domestic demand.

	Population (Mio)		Domestic Water Demand (MCM)			UFW		Total Domestic Water Demand (MCM)		
	City	Rural	City	Rural	Total	City	Rural	City	Rural	Total
2010	1.62	2.61	81	130	211	23%	50%	105	260	365
2015	1.69	3.09	84	154	238	22%	45%	108	280	388
2020	1.75	3.62	87	181	268	21%	40%	110	301	411
2025	1.8	4.2	90	209	299	20%	30%	112	299	411

With: Million Cubic Meters (MCM), and Unaccounted for water (UFW).

Table 21 shows the sensitivity of the total domestic water demand on the water consumption. The total domestic water demand is calculated the same way as before (see Table 20) for the year 2010. The population stays the same, only the unit per capita water consumption in LCD is increased. The biggest uncertainty is the population figure, as the amount of LCD can be estimated through customer surveys or the simply by dividing the metered amount of water by the population figure in sample areas with known background data. To show the possible impact of higher population figures on the water demand and the possible higher water consumption, the amount of LCD was increased. CES used a different approach to estimate the population of Rural Damascus

by multiplying the number of electricity subscribers with the average number of person per household. It resulted in a population figure of 3,65 Mio, or 1 Mio more then the current used numbers from DAWSSA.

If the water consumption is assumed to be 160 LCD, the water demand increases from 365 to 627 MCM or 58%. This figure is higher than both estimations of JICA and SMBH with 419 and 394 MCM, respectively.

Table 21: Effect of different water consumptions on total water demand compared to production for the year 2010.

	Drinking Water Demand (MCM)			Total Domestic Water Demand (MCM)			Water Production (MCM)	Water Balance (MCM)
Consumption (LCD)	City	Rural	Total	City	Rural	Total		
105	62	100	162	105	260	365	315	-50
120	74	135	210	124	320	444	315	-129
140	89	185	275	147	401	548	315	-233
160	105	245	350	171	456	626	315	-311

With: Million Cubic Meters (MCM), Liter per capita per day (LCD).

6.3 Effects on the Water Balance

In Table 22 the most current water balances from the MOI (2008) and the SMBH (2008) Study are compared to the estimated balance of this study. The balance for the year 2008 and the scenario for 2025 are listed. For completion of the balance of this study the values for total renewable resources and evaporation are taken from the SMBH Study. All other figures have been described or calculated before.

Table 22: Overall water balance and scenarios of the Damascus Basin in Million Cubic Meters (MCM).

	MOI (2008)	SMBH (2008)	SMBH (2008)	Author (2010)	Author (2010)
Year	2008	2008	2020	2010	2025
Available Resources					
Total renewable	507	499	499	499	499
Reused treated wastewater	98	125	175	100	350
Reused agricultural drainage water	203	128	91	123	89
Total available resources	709	752	765	722	938
Water Demand					
Irrigation	675	1279	911	1230	885
Domestic	312	335	466	365	411
Industry	33	21	25	21	25
Evaporative loss	5	n/a	n/a	5	5
Total demand	1021	1635	1402	1621	1326
Water Balance	-311	-883	-637	-899	-388

Note: Ministry of Irrigation (MOI) and Malaysian technical cooperation report (SMBH).

All balances have a deficit, even with the use of 772 MCM (JICA, 2007) as total available resources. The figures for demand and available resources vary greatly today as in earlier studies, preventing concrete measures in order to bring the water balance into equilibrium. But with all water balances showing a deficit, and its related problems as the dropping groundwater table, felt by the farmer and DAWSSA through reduced groundwater production rates, the objective is clear.

The water deficit is dominated through irrigation demand, which is projected double the amount than estimated by the MOI. As mentioned in Section 4.3.2, already today the MOI is using higher irrigation efficiency rates already today for their calculations. The outcome of the future scenarios still estimates a negative, but reduced water balance. The future demand is not definite, as it depends on the progress of conversion to modern irrigation methods and growing demand of the domestic sector. However, it gives an idea about the dimensions and the need to deal with this problem seriously.

As mentioned in Section 6.1.1, there is further potential on saving water in the irrigation sector by increasing the conveyance efficiency and changing of cropping pattern to less water intensive crops. These measures should be considered also in order to use the available resources sustainably and to bring the water balance into equilibrium. The focus of any project should consider the abstraction of surface flow, as the main source of irrigation supply.

The reuse of treated wastewater, according to the seasonal demand for either irrigation or aquifer recharge has two advantages. If all wastewater is collected in a decentralized system distributed over the Ghouta Area, as it is planned and partly constructed at the moment, it reduces the irrigation demand and keeps the rivers and irrigation canals clean and thereby eliminating any human exposure to untreated wastewater and its related negative effects.

7 Conclusions and Recommendations

The current situation is a falling groundwater table through overuse of the available resources. Current policies are directed at reducing the irrigation water demand as the dominating user and securing the growing domestic water demand.

The most effective scenario in reducing the agricultural water demand was the conversion to modern irrigation methods, saving 28%. Those savings can be enhanced through additional measures such as the change of cropping pattern, increase in conveyance efficiency and reuse of treated wastewater. For a general more efficient use and management of available water resources, the establishment of pilot projects for WUAs should be considered.

Demand decrease in the domestic sector through an increase in tariffs to discourage the waste of water, does not have a significant potential, as the per capita consumption is already low with about 100 LCD. Also the share of UFW in Damascus City with about 23% is very low. Whereas there is potential to decrease the water demand in Rural Damascus with a current share of about 50% UFW. The renewal of networks in Rural Damascus, the installation of flow meters and effective billing system has the highest potential to reduce the share of UFW.

A detailed study on the groundwater behavior of the Damascus Basin is needed in order to get more reliable figures on the available water resources. This could be accomplished with the set up of a groundwater model, such as MODFLOW. The coupling to WEAP - a water resource planning software, currently promoted by ACSAD-BGR, would open the possibility of a sound integrated water resource planning.

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9 Appendix

Appendix A: Crop Water Requirements (CWR) and area for seasonal and perennial crops irrigated with groundwater in the Ghouta Area (GCSAR, 2009).

Seasonal Crops irrigated with groundwater																
Plant	Area (ha)	Area (%)	Crop Water Requirement ($m^3 ha^{-1}$)												Total CWR (MCM ha^{-1})	Total CWR (MCM)
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Wheat	10455	46	115	526	1108	1452	1539	745					262	315	6062	63.4
Barley	1257	6	92	526	1096	989	964						262	321	4250	5.3
Bean (winter)	350	2	92	505	1227	1638	1424	115						265	5266	1.8
Peas (dry)	170	1	199	491	681	680							460	352	2863	0.5
Peas (green)	180	1	199	491	443								460	352	1945	0.4
Vegetables (winter)	4067	18	176	641	823								470	396	2506	10.2
Barley (fodder)	100	0	157	598	681							482	545	352	2815	0.3
Vetch	900	4	173	576	918							360	441	415	2883	2.6
Vetch (fodder)	102	0	157									658	733	571	2119	0.2
Barley and Vetch	900	4	76	383								617	545	415	2036	1.8
Anise	478	2		69	550	1298	2228								4145	2.0
Garlic	433	2		276	764	989	711								2740	1.2
Onion	184	1				602	1493	2842	3075	2326					10338	1.9
Corn (yellow)	173	1					895	2290	3280	2600	669				9734	1.7
Vegetables	1807	8			562	1174	2366	2842	1699						8643	15.6

(summer)																
Potato	983	4				788	1654	3035	3222	2326					11025	10.8
Sunflower	2	0				432	1608	2897	1172						6109	0.0
Corn (white)	75	0				572	1654	2787	1464						6477	0.5
Haricot bean	75	0					1309	2207	3105	2737	1116				10474	0.8
Water melon	25	0					619	1242	1904	821					4586	0.1
Total	22716	100													107016	121

Permanent crops and Trees irrigated with groundwater

Plant	Area (ha)	Area (%)	Crop Water Requirement (m^3 ha^{-1})												Total CWR (MCM ha^{-1})	Total CWR (MCM)
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Olive	6323	25			562	1066	1539	1931	2050	1916	1562	888	357		11871	75
Grape	2128	9				911	1539	2069	2197	2053	1562	752			11083	24
Almond	6536	26			443	989	1883	2483	2636	2190	1674	820			13118	86
Apple	6717	27			562	1066	1883	2483	2636	2326	1785	1023	545		14309	96
Forest	1314	5			325	1143	1883	2621	2841	2272	1718	1159			13962	18
Pomegranate	119	0			443	989	1883	2483	2636	2190	1674	820			13118	2
Pistachio	195	1					1079	1793	2197	2190	1674	820			9753	2
Alfalfa	1514	6			859	1220	1883	2345	2490	2326	1897	1091	310	166	14587	22
Total	24846	100													101801	324

Appendix B: Crop Water Requirements (CWR) and area for seasonal and perennial crops irrigated with surface water in the Ghouta Area (GCSAR, 2009).

Seasonal Crops irrigated with surface water																
Plant	Area (ha)	Area (%)	Crop Water Requirement (m^3 ha^{-1})												Total CWR (MCM ha^{-1})	Total CWR (MCM)
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Wheat	358	29	115	526	1108	1452	1539	745					262	315	6062	2.2
Barley	2	0	92	526	1096	989	964						262	321	4250	0.0
Vegetables (winter)	112	9	176	641	823								470	396	2506	0.3
Barley (fodder)	125	10	157	598	681							482	545	352	2815	0.4
Vetch	150	12	173	576	918							360	441	415	2883	0.4
Vetch (fodder)	125	10	157									658	733	571	2119	0.3
Barley and Vetch	101	8	76	383								617	545	415	2036	0.2
Garlic	41	3		276	764	989	711								2740	0.1
Corn (yellow)	2	0					895	2290	3280	2600	669				9734	0.0
Vegetables (summer)	69	6			562	1174	2366	2842	1699						8643	0.6
Potato	133	11				788	1654	3035	3222	2326					11025	1.5
Total	1218	100													54813	5.9

Permanent crops and Trees irrigated with surface water																
Plant	Area (ha)	Area (%)	Crop Water Requirement (m^3 ha^{-1})												Total CWR (MCM ha^{-1})	Total CWR (MCM)
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Citrus Tree	8	0	92	383	681	989	1539	1793	1904	1779	1450	888	545	321	12364	0.1

Olive	6417	36			562	1066	1539	1931	2050	1916	1562	888	357		11871	76.2
Almond	6627	37			443	989	1883	2483	2636	2190	1674	820			13118	86.9
Apple	3411	19			562	1066	1883	2483	2636	2326	1785	1023	545		14309	48.8
Forest	687	4			325	1143	1883	2621	2841	2272	1718	1159			13962	9.6
Pomegranate	66	0			443	989	1883	2483	2636	2190	1674	820			13118	0.9
Pistachio	37	0					1079	1793	2197	2190	1674	820			9753	0.4
Alfalfa	770	4		165	859	1220	1883	2345	2490	2326	1897	1091	310	166	14752	11.4
Total	18023	100													103247	234.2

Permanent crops and Trees irrigated with wastewater (Data from GCSAR, 2010)

Plant	Area (ha)	Area (%)	Crop Water Requirement (m^3 ha^{-1})												Total CWR (MCM ha^{-1})	Total CWR (MCM)
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Vetch	2500	47	27	383	978							688	596	146	2818	7.0
Barley (fodder)	2363	44	27	242	639							501	419	18	1846	4.4
Corn (fodder)	500	9						1436	2554	3233	1262				8485	4.2
Total	5363	100													13149	15.6

إدارة الطلب على المياه كأداة لتقليل العجز في الموازنة المائية لحوض دمشق سوريا

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ملخص

إن حوض دمشق كوحدة هيدرولوجية يواجه عجزا مائيا حيث أن كمية المياه المستخدمة أكثر من التغذية الطبيعية مما أدى إلى إنخفاض منسوب المياه الجوفية في هذا الحوض والذي بدوره أدى إلى تناقص كمية المياه المتوفرة لاغراض الشرب والزراعة.

تم في هذه الدراسة تقييم عدد من ا لسيناريوهات التي تعتمد مبادىء الإدارة المتكاملة للموارد المائية من أجل تقليل العجز في الموازنة المائية في حوض دمشق. ركزت هذه السيناريوهات على التوفير في المياه المخصصه للإستخدامات المنزلية والزراعية والتي تشكل 80% من الإحتياجات الكلية.

قدر الوفر المتوقع في الإحتياجات الزراعية بحوالي 28% عن طريق إستخدام تقنيات الري الحديثة بالإضافة إلى إمكانية المزيد من التوفير عن طريق تغيير النمط الزراعي وتحسين كفاءة شبكة الري. أما في قطاع الإستخدامات المنزلية فإنه من المتوقع إزدياد الطلب بسبب النمو السكاني المطرد والذي بدوره سوف يستهلك الوفر المتوقع في القطاع الزراعي. كما قدر مجموع الإحتياجات المائية للإستخدامات المنزلية والزراعية في العام 2025 بحوالي 84% من الإحتياجات الحالية والتي هي أكثر من كمية المياه المتوفرة مما يعني عجزا في الموازنة المائية.

لتحقيق الإدارة المستدامة للموارد المائية في حوض دمشق فإن هناك حاجة الى المزيد من الجهود لتقليل الطلب وزيادة فاعلية الإستخدام بالإضافة إلى إعادة الإستخدام.